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The Urogenital System Of Myxinoids

THE UROGENITAL SYSTEM OF MYXINOIDS

BY

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INTRODUCTION

As is well known, Johannes Müller was the first to investigate the urogenital system of the Myxinoids, describing briefly both male and female of Bdellostoma forsteri and the European Myxine glutinosa. Since his work much has been written regarding this subject. The investigators of the excretory organs include W. Müller ('75), Kirkaldy ('94), Semon ('96), Spengel ('97), and Maas ('97), all of whom worked upon the Myxine found in European waters.

Weldon ('84) and Price ('10) are the only ones who have published a description of the excretory apparatus of Bdellostoma. The former investigated Bdellostoma forsteri, the latter Bdellostoma stouti. Both of these descriptions are confined almost entirely to the structure and probable function of the pronephros, and are comparatively incomplete. Scarcely anything is said about the mesonephros. Price ('96a, '96b, '97, '10) has, however, given us a very detailed account of the development of the excretory system in Bdellostoma stouti which throws much light upon the adult condition. Semon ('96) devotes one paragraph to a comparison between the pronephroi of Myxine glutinosa and Bdellostoma bischofi.

After J. Müller, Thompson ('59) and Streenstrup ('63) were the next writers upon the generative organs of the Myxinoids, each giving a short account of the mature ova of the European Myxine. W. Müller ('75) contributed many points regarding oogenesis in Myxine and gave the first description of the minute structure of the testis. In 1886 Cunningham added a few more points regarding the reproductive elements of Bdellostoma forsteri, and in 1887 he published the first detailed description of the sexual organs and products of Myxine

glutinosa, introducing the subject of protandric hermaphroditism. Nansen ('87) supplemented Cunningham's description with the results of further investigations which led him to agree with Cunningham that Myxine glutinosa is a protandric hermaphrodite. Cunningham ('92) next contributed a rather lengthly discussion of spermatogenesis in Myxine. Ayers ('93) published the first description of the reproductive system of Bdellostoma stouti, and soon after Dean ('99) gave an account of the structure of the eggs and development of the embryo. The last articles that have appeared regarding this subject are those by A. and K. E. Schreiner ('04, '05, '08) which consist of a description of the generative elements of Myxine glutinosa and a very thorough discussion of spermatogenesis in Myxine glutinosa and Bdellostoma burgeri. Besides the foregoing investigators there are many who have made more or less small contributions to our knowledge of the genital apparatus in Myxinoids.

The literature contains only a very meagre description of the mesonephros and the reproductive elements of Bdellostoma and practically nothing regarding the urogenital system of the North-American Myxine. The latter animal differs from the European Myxine glutinosa sufficiently to cause some writers to regard the two as different species. Girard ('58) found specific differences "in the external aspect of the snout and buccal aperture, the insertion and proportional development of the tentacles, the form of the body, and **** the presence of a membraneous fin-like expansion along the abdomen", and proposed the name Myxine limosa for the North-American species. Putnam ('73), who compared specimens obtained off the north-eastern Atlantic coast, from the straits of Magellan, and from the Museum of Comparative Zoology at Liverpool collected off

the English coast, however, considers the American animal as merely a variety of Myxine glutinosa. The writer has been unable to obtain specimens of the European animal for comparison. Judging from the literature, there is a very great difference in the sizes of the two animals. Putnam's specimens from Liverpool measured 10½ to 12 inches long (26 to 30 cm.). Nansen, using animals caught near Bergen, and Schreiner, who caught hundreds in Dröbaksfjord, reported the largest adults as 35 cm. long. From Cunningham's accounts it is to be inferred that the largest adults caught by him off the English coast and near Bergen were from 25 to 42 cm. long, most of them being from 33 to 35 cm. and containing the largest eggs. None of the investigators of the European Myxine report animals longer than 42 cm. The single North-American specimen used by Girard was 11½ inches long (about 29¼ cm.), and the one examined by Putnam was 12 inches (about 30½ cm.). The writer has been unable to find in the literature any other measurements of the North-American Myxine. The adult animals used in the present study range from 50 to 79 cm. in length, averaging 62 cm., which is almost twice the length reported for the adult European Myxine. Three specimens measuring in length 31, 33 and 36½ cm., respectively, are in a very young stage, the genital ridge being only 2 to 3 mm. wide along its entire course and the eggs being nothing more than dots. Size alone, of course, is not a specific character, but such a great difference as the above is suggestive.

In view of the fact that only two comparatively short descriptions of the pronephros of Bdellostoma have been published, and that the mesonephros of Bdellostoma and the entire urogenital system

of the North-American Myxine are still undescribed, it seems desirable:

First, That the pronephros of Bdellostoma be re-examined, in order, if possible, to collect additional data which may illuminate some of the uncertain or disputed points in regard to its structure;

Second, That the mesonephros of Bdellostoma be described more fully;

Third, That the entire excretory and reproductive systems of the North-American Myxine be described and compared with those of Bdellostoma and of the European Myxine, in order to ascertain whether they present any specific differences or add anything to our comprehension of the urogenital system in Myxinoids.

Materials and Methods

The Myxine used in this study consist of 20 specimens which were caught at South Harpswell, Maine, during the summers of 1914 and 1915. Three of the animals are immature females, #7, #17 and #18, measuring 36½, 33, and 31 centimeters, respectively. All the other specimens are adults ranging from 50 to 79 cm. and averaging 62 cm. in length. Only one specimen is 50 cm. long and the largest eggs in it are 8 mm. long. The next longest specimen measures 55 cm. and its largest eggs are 22 mm. long.

Twenty-four specimens of Bdellostoma stouti, 9 males and 15 females, which were caught at Pacific Grove, California, comprise the Bdellostoma material. The smallest is an immature male 33 cm. long. The other males are adults, ranging from 36 to 42 cm. in length, and all the females are adults which range from 34 to 40 cm.

All the animals were killed and preserved in 10% formalin,

and later were transferred to 70% alcohol.

The study of the pro- and mesonephros was made from sections stained in Delafield's haematoxylin and eosin. Toto mounts of these organs, cleared in xylol and imbedded in damar, were also used.

The work was done in the Zoological Laboratories of the University of Illinois under the guidance of Dr. J. S. Kingsley. I wish to acknowledge my sense of obligation to Dr. Kingsley for his kindly interest and helpful suggestions, always willingly given.

II. OBSERVATIONS

1. Excretory System

The investigation of the excretory apparatus is based upon Bdellostoma stouti, and the results will be presented by describing the organs of this animal and by interjecting, from time to time, comparative notes regarding the same organs in the American Myxine. Unless, therefore, it is specifically stated otherwise, the content of the following discussion refers to Bdellostoma stouti.

Pronephros

The right pronephros lies in the right pericardial cavity immediately dorsal to the portal heart and along the dorso-lateral surface of the alimentary canal, parallel to the dorsal aorta. In figures 1 and 3, which illustrate the position of the right pronephros of Bdellostoma and Myxine, respectively, in the pericardial cavity, the lateral wall of the cavity has been cut away, but the edges of the pericardium which form the pericardo-peritoneal foramen are shown. The pronephros lies along a large diverticulum extending posteriorally from a vein which is called by Jackson ('01) the anterior portal and by Cole ('14) the right anterior cardinal vein.

I have had no opportunity to examine injected specimens, but from a study of serial sections the writer agrees with Price ('10) that this vessel is merely a diverticulum with no posterior outlet. In Myxine glutinosa, however, Cole ('14) has shown that this vein extends posteriorly after leaving the pronephros and enters the supra-intestinal vein. In a single poorly injected specimen of the North-American Myxine the writer found a small twig extending posteriorly from this vein toward the supra-intestinal vein and a larger branch going to and entering the right postcardinal vein. In Bdellostoma the vein varies in diameter from 0.35 x 0.40 mm. to 0.65 x 0.85 mm. at a point about the middle of the pronephros. The vein is always between the two folds of pericardium by means of which the pronephros is attached to the dorsal aorta and to the wall of the alimentary tract (fig. 5).

The pericardium completely envelopes the pronephros. It encircles each tubule where the latter extends into the pericardial cavity. At the distal end of each tubule the pericardium is continuous with the columnar epithelium which lines the tubule. This enveloping pericardium extends farther down between the tubules in Bdellostoma than in Myxine.

In all the specimens examined the right pronephros was located in somites 31 and 32, counting the somite in which the eye is located as the first. In only one specimen, a young female, did the pronephros occupy but one somite. In all the other specimens it began in somite 31 and projected into somite 32.

The <u>left</u> pronephros lies in the left pericardial cavity immediately dorsal to the auricle and along the dorso-lateral surface of the alimentary tract, parallel to the dorsal aorta. The left pronephros, also, is connected to the aorta and to the alimentary tract

by a fold of pericardium (fig. 5). The line of attachment of this fold of pericardium embraces from one-fourth to one-half of the width and about three-fourths of the length of the median-lateral surface of each pronephros. In all the specimens the left pronephros is slightly posterior to the right, and usually lies in somites 32 and 33. Both right and left pronephroi lie about one millimeter to the right and left of the dorsal aorta, as shown in figures 45 and 46.

The left pronephros lies along a vein extending posteriorly from the left anterior cardinal. From his sections the writer could not trace this vein to any posterior connection in Bdellostoma, and concludes with Price ('10) that it is merely a diverticulum. In Myxine, however, the writer found that this vein continues posteriorly and enters the large vein formed by the union of the two posterior cardinals (fig. 4), the left ductus Cuvieri of Cole ('14). Like the right vein, this vein along the left pronephros lies between the folds of pericardium which attach the pronephros to the dorsal aorta and to the digestive tract. Since no name has been given to these veins, hereafter in this discussion they will be referred to as the right and left pronephric veins. The position of the left pronephros in the pericardial cavity is represented in figures 2 and 4.

In shape the pronephros is never exactly the same in any two specimens nor on both sides of the same specimen. In most cases, however, it is somewhat three-sided, though it is sometimes flat on the attached side only and the remaining surface is rounded. The ends always taper more or less, the anterior end usually being the more pointed. This is due to the fact that at its anterior end the pronephros almost invariably consists of only one or two small lobules, while the posterior end is usually composed of several lobules

crowded together in a compact mass. Figures 7 to 11 represent pronephroi taken at random and illustrate the variation that may occur in the shape. Figure 11a represents a cross section of a pronephros and illustrates the three-sided form. When three-sided the head-kidney is more or less wedge-shaped, flattened dorso-ventrally with the sharp edge of the wedge opposite the point of attachment. In this condition the pronephros has the appearance of having been subjected to pressure, probably due to the distended portal heart and auricle pushing it against the dorsal body-wall.

The size of the pronephros is also quite variable, as the following few measurements will indicate:

Specimen	Side	Length	Surfaces Dorsal	Ventral	Lateral	
#5	Right	6	1-3/4	1-1/2	1-1/4	mm.
	Left	5	2	2	3/4	"
#7	Right	5-3/4	1-3/4	1-3/4	3/4	"
	Left	5	1-1/2	1-1/4	3/4	"
#16	Right	6	2-1/4	2	1	"
	Left	5	1-3/4	rounded		
#18	Right	5	2	2	1	"
	Left	7	2	2	1/2	"

It was observed that the right pronephros is usually slightly larger than the left. In none of the specimens was a pronephros found even one-half as large as those of Bdellostoma forsteri as reported by Weldon ('84), nakely 20-25 x 5-7 mm. There is no correlation between the size of the pronephros and the length of the animal in Bdellostoma. Weldon does not give the length of the animals examined by him, hence we do not know whether the great difference in the sizes of the pronephroi of Bdellostoma stouti and Bdellostoma forsteri may be explained by a difference in the length of the two animals. The adult Bdellostoma used in the present investigation

range from 33 to 42 centimeters long, averaging 38 centimeters. The pronephroi represented by the above table are all from adult animals.

The writer has been able to find only one statement regarding the size or shape of the pronephros in the adult European Myxine. W. Müller ('75) mentions that they are 'länglich', 3 to 4 centimeters long. Following is a table of dimensions of a few pronephroi of the North-American Myxine:

Specimen	Length of Animal	Side	Length of Pronephros	Surfaces: Dorsal	Ventral	Lateral:
#2	58 cm.	Right	5-1/2 mm.	2	2	3/4mm.
		Left	5-1/2 "	2	2	3/4 "
#6	61 "	Right	7 "	2-1/2	3	1-1/2 "
		Left	6 "	2	2-1/2	1 "
#13	63 "	Right	8-1/2 "	2-1/2	2-3/4	1/2 "
		Left	7 "	2	2-1/4	1-3/4 "
#1	63 "	Right	9 "	4	4	2-1/2 "
		Left	8-1/2 "	3	3	3 "
#3	64 "	Right	9 "	3	3	1 "
		Left	8 "	2	2	1 "
#12	67 "	Right	6 "	2	2	1 "
		Left	10 "	2	2	1 "
#10	68 "	Right	10-1/4"	1	4-1/2	4-1/2 "
		Left	8-1/2 "	5	5	2 "

As is indicated by the above tables, the pronephroi of Myxine are considerably larger than those of Bdellostoma. This is to be expected from the great difference in the size of the adult animals. The writer found that there is a correlation between the size of the pronephros and the length of the animal in Myxine, but not a sufficiently large number of specimens was available to prove this to be constant. The largest pronephroi (those of Myxine #10) are in an animal which has the appearance of being quite old. The skin is darker than usual, very thick, wrinkled and hard, the muscle fibers in the body wall are large and coarse, the walls of the alimentary canal are very thick, the liver and gall bladder are very large and coarse. In this specimen the pronephroi are a very dark brown color,

in all the other specimens and in all the Bdellostoma examined the pronephros is gray. It is probable that the size of the pronephroi is more correlated with the age than with the length of the animal. The right pronephros of Myxine was found to be almost always larger than the left.

Price ('04) found that at some stage of embryonic development of Bdellostoma stouti an excretory tubule appears in each somite from the 11th-13th to the 79th-82nd. That is to say, in the embryo pronephric tubules are present in the same segemnts with gills. As the gills shift posteriorly (Dean, '97) these pronephric tubules are pushed along behind them and eventually become crowded together in a "small, compact body, the pronephros of the adult, in the region a little posterior to the thirtieth segment" (Price, p. 132). Price does not mention anything in regard to the history of the veins connected with the tubules in this movement posteriorly.

As would be expected, there is a limitless variety in the minute structure of the pronephroi. It is well known that each pronephros is composed of a large number of small tufts or lobules of tubules which open separately into the pericardial cavity. Usually there are fewer of these lobules at the anterior end than at the posterior, and one or two lobules may be entirely separated anteriroly from the balance of the pronephros. Figure 12 represents a reconstruction on millimeter paper of the right pronephros of Bdellostoma #15. This pronephros was cut in transverse sections, each 10 microns thick, and it will be used as a basis for the description of the minute structure of the head-kidney of Bdellostoma, as follows:

Histology

The tubules in each of the two most anterior lobules anasto-

mose inwardly and form a single tubule which unites with one similarly formed from the other lobule, and the single tube thus formed constitutes the central duct of the pronephros. The first appearance of the central duct occurs in the 10th section from the anterior end of the pronephros. All of the pronephroi of Bdellostoma stouti examined by the writer have a central duct which is so evident that it can not possible be interpreted as anything else. Price ('10) found a central duct in the head-kidney of Bdellostoma stouti, and Weldon ('84) described one for Bdellostoma forsteri. Semon ('96) thought that Weldon was mistaking the venous sinus (pronephric vein) for a central duct, but Weldon's description of the duct coincides so nearly with the condition in Bdellostoma stouti that it seems very probable that Bdellostoma forsteri has a central duct in the pronephros. In the 10th section from the anterior end of the pronephros the lumen of the duct is 0.02 mm. wide, but it enlarges immediately and is 0.15 mm. at the widest part. The duct proceeds posteriorly, entering the pronephric vein in section 20 and ending blindly in the vein in section 48. From its beginning this short segment of the central duct is surrounded by a mass of large, deeply stained nuclei, which will be referred to hereafter in this discussion as the 'central mass' and which will be described in detail later. This mass is distributed somewhat regularly around the central duct, now more on one side, now more on the other. Some idea of its gross appearance may be had from figure 12. At its widest part the mass measures 0.21 mm. from its outer edge to the lumen of the duct, and it extends 0.14 mm. beyond the posterior end of the duct.

No trace of the central duct is again seen until section 52 is reached. Here the tubules of one lobule unite into a single tube,

and the latter forms the beginning of the central duct. The lumen of this segment of the duct is 0.05 mm. in diameter at first, but measures 0.09 mm. at the widest part. The duct proceeds posteriorly to section 60, receiving in its course the tube from another lobule. In section 60 the duct enters the pronephric vein, and remains in it to section 80 where it ends blindly. From its beginning this segment of the duct is also surrounded by a central mass like the one around the first segment of the duct. In transverse section the mass is circular in outline and is distributed somewhat regularly around the lumen of the duct. At its widest part the mass measures 0.16 mm. from its outer surface to the lumen of the duct. Only two lobules of the pronephros are connected with this segment of the central duct.

The third segment of the duct appears in section 90, and is formed by the main tube of one lobule. In this section the lumen of the duct is 0.05 mm. in diameter, but becomes as wide as 0.20 mm. This segment of the duct extends to section 150 and there breaks up to form the tubules of three lobules. Altogether there are four lobules connected with this segment. The duct runs parallel to the pronephric vein, and up to section 115 is separated from the latter by a wide layer of connective tissue. In this distance one vein one millimeter wide and another three millimeters wide permit blood to flow from the pronephric vein into capillaries which run between the tubules of the pronephros. At section 115 the duct widens abruptly and extends downward in the the pronephric vein. In the vein the duct becomes sheathed in a central mass which resembles in all respects that masses which surround the first and second segments of the duct. In section 117 the duct opens through the central mass

into the lumen of the pronephric vein. This opening is 0.05 mm. wide. Another such opening 0.09 mm. wide occurs in section 250, and a third 0.04 mm. wide in section 320. These openings are not breaks or tears, but are natural apertures lined by a single layer of squamous epithelium which is continuous with the columnar epithelium of the duct on the one hand and with the endothelium of the pronephric vein on the other. Figure 20 represents one of these openings. At least one, often more, such opening connecting the lumen of the central duct with the lumen of the pronephric vein was found in every pronephros of Bdellostoma examined. These openings occur only through the central mass, never through the walls of the central duct when not surrounded by the central mass. To return to the description, the duct remains in the central mass to section 137 where it leaves the vein and breaks up into the tubules of three lobules. The central mass, however, continues in the lumen of the vein independent of the duct, and in section 147 the fourth segment of the central duct appears in it. The central mass projects into the pronephric vein as indicated in figure 12 and has a cylindrical shape. Between sections 137 and 147 it is 0.30 x 0.40 mm. in transverse section.

The fourth segment of the central duct begins as the result of the anastomoses of the tubules of four lobules whose main tubes unite near section 150 and form the central duct. In this section the duct is 0.05 mm. wide. At first the duct lies in the connective tissue at the base of the pronephros, but in section 157 it bends toward and enters the central mass in the vein. Here the lumen of the duct is 0.27 mm. wide. In this segment one side of the duct remains closely applied to the connective tissue at the base of the pronephros and retains its columnar lining, while the other side extends along the cen-

tral mass to section 200 where it bends toward its fellow, thus narrowing the lumen of the duct considerably, and the segment ends by the duct branching into the tubules of a single lobule. There are eleven lobules connected with this segment of the duct. The central mass continues without interruption in the pronephric vein to section 240 where the fifth segment of the duct enters it. That is to say, the central mass extends from section 200 to section 240 (a distance of 0.40 mm) entirely disconnected from the central duct. In the region of the fourth segment the central mass resembles in every respect that around the prededing segments of the duct. In the portion between sections 200 and 240, however, the mass changes its shape in transverse section from circular to elongated, measuring 0.15 x 0.55 mm. in the largest portion. Figure 20 represents the shape of the mass at this place. This figure also indicates the relation of the size of the mass to the lumen of the vein. In this particular pronephros the duct and the mass together in the largest parts never occupy more than about one-half of the lumen of the vein as viewed in transverse section. In one specimen, however, the central duct is so large that it, together with the central mass, almost entirely obstructs the lumen of the vein. Between sections 205 and 230 the pronephric vein opens directly between the tubules as a large sinus (fig. 20), and another such sinus lies between sections 255 and 300. At all other places, however, there is a strip of connective tissue from 0.01 to 0.05 mm. wide, or even wider, between the pronephros and the vein. In one specimen, though, the vein opens directly into the spaces between the tubules along the entire base of the pronephros. But even here the pronephros stands upon the vein as illustrated in figure 20, so that in no sense can the head-kidney

be said to lie buried within the vein, a misleading statement which occurs very frequently in the literature. Where the vein opens between the tubules as a sinus the capillaries, which otherwise carry the blood between the tubules, have broken down and only the pericardial sheath and the endothelium of the sinus confine the blood in the intertubular space. These vascular spaces between the tubules are not 'sinusoids' according to Minot's use of the term. The pronephric tubules do not invade the vein, for, as Price ('10) has shown, the branching to form new tubules always occurs in a direction away from the pronephric vein, "just back of the nephrostomes".

The fifth segment of the central duct begins in section 212 where the tubules of one large lobule unite into a single tube which widens to form the duct. The latter extends posteriorly in the connective tissue at the base of the pronephros parallel to the pronephric vein to section 240, increasing gradually in width from 0.04 mm. to 0.15 mm. In this section the duct bends downward so that one side enters the central mass, which still remains in the vein. The wall of the duct which lies toward the pronephros retains its columnar structure, but the wall which lies in the central mass breaks down completely soon after entering the mass and presents a jagged appearance, and the nuclei bordering the lumen have no definite arrangement. In sections 243 to 255 the central duct opens through the central mass into the lumen of the vein. The mass is similar in all respects to that surrounding the preceding segments of the duct. In section 260 the duct divides, one branch entering a lobule and breaking up into tubules, the other continuing posteriorly in the central mass and ending blindly in it at section 274. In section 276 the duct begins again as a part of the sixth segment, just opposite the blind ending

of the fifth segment. There are six lobules connected with the fifth segment of the duct.

The sixth segment of the duct arises in section 273 from the union of the tubules of one lobule. The duct enters the central mass in the vein in section 300, and is here 0.12 mm. wide. A small twig extends anteriorly in the mass to section 276 where it ends blindly and is separated by only one section from the end of the fifth segment of the duct. Undoubtedly at one time the fifth and sixth segments of the duct were connected at this point. The sixth segment extends posteriorly through the central mass to section 380 where it ends as a single tubule which runs out of the vein and opens into the pericardial cavity. In sections 318 to 323 the duct opens through the central mass into the pronephric vein, and in this region the duct and neighboring tubules contain many blood corpuscles. In section 350 the duct leaves the central mass and the columnar cells of the walls of the duct become double their usual length and are thrown into longitudinal folds like those of the mesonephric duct, to be described later. This folded condition of the epithelial walls of the duct continues to section 370; then the cells diminish in length to the normal size for the tubules, and the duct here ends as a single tubule, as explained. There are six lobules connected with the sixth segment of the duct.

The seventh segment of the central duct begins in the central mass in section 340 beside the sixth segment. It continues in the mass, which still lies in the pronephric vein, to section 365 where it leaves the mass and vein and divides into two branches, one of which ends by branching into the tubules of a lobule and two single tubules, the other breaks up into the tubules of the four most post-

erior lobules of the pronephros. The lobules connected with this segment of the duct are in such a compact mass that they can not be counted with any degree of certainty.

The eighth and last segment of the central duct arises in the central mass in section 370 beside the seventh segment. The mass continues around the duct to section 380 and there ends, remaining in the lumen of the vein. The duct proceeds posteriorly, and in section 385 divides into three tubules, each of which leaves the pronephric vein and enters the Bowman's capsule of the Malpighian body of the pronephros, opening into the capsule by a nephrostome. There are no lobules connected with the eighth segment of the duct.

Price ('14) suggests that perhaps each lobule of the pronephros represents a single original tubule and its secondary branches. This is scarcely probable, for there is a total of 31 lobules connected with the first six segments of the duct in the above described pronephros, while those of the seventh segment could not be counted with accuracy but there are at least four. If the most anterior original tubule lay in somite 11, then there could be only 21 tubules at most to and including somite 32, the definitive position of the tubules after they have been pushed posteriorly by the gills. In the pronephros under discussion, however, there are at least 35 lobules.

In Bdellostoma none of the tubules in any of the pronephroi examined by the writer show any signs of degeneration, and the lumen of each tubule opens into the pericardial cavity at one end and is continuous, either directly or indirectly, with the lumen of the central duct. The lumen of almost every tubule is filled with a coarsely granular coagulum which is more or less shredded into long processes resembling flagella (fig. 16). These processes are attached

at one end to the columnar cells, usually one to a cell, and the free end extends inward toward the base of the tubule, that is, toward the central duct. The lumen of the central duct sometimes contains a comparatively small amount of this coagulum. The writer was unable to demonstrate cilia in the pronephric tubules, but it is probable that his material was not suitably preserved to permit these to be seen if present.

The tubules are very simple in structure. Each is a cylinder consisting of a single layer of columnar cells which are continuous at the mouth with the pericardium and at the base with the columnar cells of the central duct. The mouths of the tubules are sometimes funnel-shaped (fig. 13, but are usually constricted (fig. 14). The columnar cells which constitute the wall of the tubules are approximately the same size in all the tubules, varying somewhat around 0.0135 mm. long by 0.004 mm. wide. The nucleus is always at the base of the cell and occupies the entire width and from one-half to two-thirds its length. At the base of the cells the cell-walls fuse to form a thin basal membrane, the outer limit of the tubule. When connective tissue occupies the space between the tubules it lies next to the basal membrane, and when a blood sinus fills the inter-tubular space the endothelium of the sinus usually lies against the basal membrane, completely surrounding the tubule (fig. 15). The lumen is practically the same in diameter in all the tubules, and the outside diameter of the tubules is likewise approximately the same.for all tubules. The specimens of Bdellostoma examined were within a few centimeters of being the same length, and the dimensions of the tubules are about the same in all the pronephroi examined. At the mouth of the tubule the lumen narrows slightly, but otherwise is approxi-

mately the same diameter throughout. Often, however, a tubule is constricted in one or two places. The lumen is approximately 0.0216 mm. wide, and the outside diameter of the tubule is about 0.054 mm.

The protoplasm of the columnar cells of each tubule is coarsely granular, and the boundary of the cell facing the lumen is usually marked by many granules and one or two long processes which consist of granules (fig. 16). The nuclei are more or less oval and always contain many large deeply stained bodies. The cells of the tubules are continuous with those of the central duct at the proximal end and with those of the pericardium at the distal end.

The cells of the central duct are also columnar and are usually longer than those of the tubules. The character of the cytoplasm and nuclei in the duct cells is practically the same as in the tubules, and the basal membrane of the latter is continuous with the basal membrane of the former. The cells of the duct in a given pronephros vary in length at different points, but any increase or decrease is gradual. They may be as long as 0.0324 in the midregion of the pronephros. The diameter of the lumen of the duct varies widely in an individual specimen. It may be as small as a tubule in places, then increase to several times that width. The duct and its lumen may be continuous throughout the entire length of the pronephros or may be broken up into disconnected segments. The most continuous duct was found in a young male. The duct in this specimen also has the least amount of central mass connected with it, and the mass is almost entirely confined to the posterior end of the duct.

The structure which has been referred to as the 'central mass' was first described by Kirkaldy ('94) for Myxine, and the writer has

adopted her name for it. It is possible that Weldon's lymphatic tissue may have been the same thing as this central mass, but his short description does not enable us to be positive. This mass of tissue has been the subject of much discussion by investigators of the pronephros of Myxinoids. Weldon ('84) described a mass of lymphatic tissue which he found at the posterior end of the head-kidney of Bdellostoma forsteri. He states that the central duct ends posteriorly "in a mass of tissue * * * * * * * resembling the trabecular supporting tissue of a lymphatic gland". Into this mass strands of blood vessels pass from the glomerulus which lay beside it. Upon the basis of this lymphatic tissue Weldon thinks the pronephros becomes transferred into and functions as a suprerenal body. Kirkaldy found a difference in the mass in animals without ova and those with them. In the former the mass was divided into separate parts, and each part was regarded as a glomerulus supplied with a capsule inside of which was a characteristic loop (her fig. 2). In an animal with ova she found no central duct or glomerulus in the pronephric vein, but their former position was occupied by a mass of small cells with small nuclei and larger cells with large, round, and deeply stained nuclei (her fig. 7). Capillaries were numerous in this mass. Kirkaldy regards the mass as the degenerating central duct of earlier stages, hence Myxinoids may be considered as representing a stage in the phylogenetic reduction of the head-kidney, and the latter may represent the mesoblastic part of the supra-renal bodies.

Semon ('97) regards this mass as the glomeruli of the head-kidney. Eventually, however, the pronephros becomes transformed into a suprarenal body. He found the mass rich in blood vessels.

Spengel ('97) thinks this mass was never glomerlular, but that

it is either a suprarenal body or a lymph organ, and that it is the result of a metamorphosis of the inner ends of the pronephric tubules.

Maas ('97) thinks the mass differs distinctly from a glomerulus. Blood vessels occupy only a little space in it, and it is greatly dissimilar to tubule epithelium. It resembles stages in the development of the Müllerian duct of higher animals, especially reptiles. It is also not unlike the medulla of suprarenals.

Price ('10) evidently saw this mass, but does not describe it. He states that "in places the wall of the duct may become greatly thickened by an increase in the number of epithelial cells. These change their shape, and become much more loosely arranged, so that the tissue loses entirely the structure of columnar epithelium." Price adds that these thickenings are not supplied with arteries.

In specimens with a duct which is continuous throughout the entire length of the pronephros, the central mass appears only in the posterior third of the pronephros where it surrounds the duct and lies in the pronephric vein. In most of the specimens, however, the duct is broken up into segments which are not connected with each other, and that part of each segment which lies in the vein is surrounded by the central mass. The mass is found only in the pronephric vein (a very small quantity may be connected with the duct immediately before it enters the vein). A typical distribution of the mass is represented by figure 12. It may project into the vein like a glomus, one side remaining in contact with the base of the pronephros, or it may lie in the lumen of the vein completely surrounded by blood and be attached to the base of the pronephros at one end only. The central mass is found only in connection with the central duct and is always

attached to the latter, though one end of the mass may extend in the pronephric vein some distance (as much as 40 sections, 0.4 mm) beyond the end of the lumen of the duct. The mass is more or less cylindrical, though in places it may be considerably widened as if bent upon itself and then is elongated in transverse section. In none of the specimens does it entirely fill the lumen of the vein. In those pronephroi in which the duct is almost continuous, however, the lumen is so great in diameter that the duct, together with the central mass surrounding it, almost entirely fills the lumen of the vein, leaving only a very narrow space between the mass and the vascular endothelium. The endothelium of the pronephric vein is continuous around the mass (figs. 17 and 22), but is here much thinner than when lining the vein, and its nuclei can be observed only now and then. The surface of the mass is smooth convoluted.

Figure 18 represents a transverse section through the central mass, and illustrates the typical condition in Bdellostoma. It is composed of a large number of cells, the nuclei of which are more or less oval in shape. The latter are of various sizes, the largest and most numerous averaging 0.0054 x 0.0108 mm. These nuclei are not distributed in any regular manner, large, small and intermediate sizes are mingled in all parts of the mass. Also, there is no regularity in the manner of their arrangement; some are isolated completely from surrounding neighbors, others are collected in groups of two or three, and again six or eight may be closely crowded together in a mass. There is no definite cellular structure observeable in the central mass. Most of the nuclei contain many large, deeply stained granules, but many have only a nuclear membrane with no granules inside. Many of the nuclei have no cytoplasm surrounding them, while others are im-

bedded in what resembles the granular cytoplasm in the cells of the central duct and tubules. This granular cytoplasmic ground-work is scattered throughout the central mass and in places is drawn out into slender processes which resemble those found in the tubules. There is no connective tissue in the central mass. In an occasional transverse section of the mass there are one to three or four giant nuceli, but these are not frequent in Bdellostoma. About one hundred sections of the mass were examined before a section containing one of these giant nuclei was found. Occasionally such nuclei occur in the walls of the duct or of the tubules near the central mass. These giant nuclei are much more deeply stained than are the other nuclei of the mass, and the cytoplasm, which always surrounds them, stains like that of blood corpuscles but much more deeply. These giant cells are interpreted as greatly enlarged blood corpuscles. They do not have the elongated characteristic shape of the blood corpuscles, but are usually rounded and quite irregular in outline. In the central mass they are surrounded by a very thin membrane which is interpreted as endothelium, although no nuclei can be observed in it. In the walls of the duct or tubules, however, nuclei occur in the membrane surrounding the giant blood corpuscles and here it is undoubtedly endothelium. These giant cells are also frequently seen in capillaries which occur in the connective tissue surrounding the mesonephric duct, and here there is no doubt that they are in blood vessels.

Excepting the giant corpuscles just described, the writer rarely found a blood corpuscle or blood vessel in the central mass. An attempt was made to find blood vessels entering the mass, but without success. The blood corpuscles have a distinctly characteristic shape and appearance and the cytoplasm stains more deeply in eosin

than that of any of the other cells in the pronephros, hence the corpuscles are easily discerned in any tissue. There are many spaces in the central mass, but they are not lined by endothelium and never contain blood corpuscles. Furthermore, the writer found no vessels leaving the central mass to enter the vein or any surrounding tissue. Also, natural appertures in the endothelial wall of the mass were diligently but vainly sought; the mass is completely shut off from the blood in the vein. One series of sections is especially well stained to demonstrate this fact. The blood corpuscles are stained a deep, yellowish-red, which is strikingly different from the pale blue of the central mass. The blood corpuscles surround the latter as a dense mass which almost fills the lumen of the vein. On account of the striking contrast in stain a single blood corpuscle inside the central mass would be instantly recognized if present. But none was found. Price ('10), also, found no blood vessels in the central mass in Bdellostoma.

When not surrounded by the central mass, the central duct retains its columnar walls, but loses them upon entering the mass. The walls break down completely and the cells become scattered in the mass. The lumen of the duct many continue in the mass, but it has no organized lining and is bordered by nuclei and strands of cytoplasmic ground-work (fig. 29). The columnar lining of the central duct is never continuous with the epithelial sheath around the central mass. In view of this fact, it is difficult to regard, as Semon ('96) does, the central mass as a series of glomeruli into whose Bowman's capsules the tubules of the pronephros enter through their 'Innentrichter', for Semon ('96, '97) himself has shown that in the mesonephros the columnar wall of the tubule of a Malpighian body is

continuous with the squamosal epithelial wall of the Bowman's capsule. Furthermore, in Bdellostoma the writer never found a tubule entering the central mass. The tubules enter the central duct and the latter alone enters the central mass, hence in Bdellostoma Semon's 'Innentrichter' of the pronephric tubules really open into the central duct. Therefore, the inner ends of the pronephric tubules cannot correspond to that end of the tubule of a mesonephric Malpighian body which opens into the Bowman's capsule, and hence the central mass of the pronephros cannot correspond to the glomerulus of a Malpighian body of the mesonephros.

In every pronephros of Bdellostoma examined by the writer the central mass has one or more openings through which the central duct communicates with the lumen of the pronephric vein (figs. 12, 20, 21, 22). These openings are natural, and the endothelial sheath which surrounds the central mass lines the sides of the openings. In the lumen of the duct near these openings, or even projecting into them, there is almost always a rounded collection of nuclei and granules, which is more deeply stained than the central mass. The nuclei and granules do not resemble blood corpuscles, but have the appearance of waste particles. These openings do not occur in the central duct at any place where the latter is not surrounded by the central mass, nor do they occur in all those segments of the duct which are ensheathed by the central mass. There is no regularity in the location of these openings, except that they are always confined to the posterior half of the pronephros. As is shown by figures 20, 21 and 22, by means of these openings the lumen of the pronephric vein is in actual communication with the pericardial cavity through the central duct and the tubules. Near the openings blood corpuscles are numer-

ous in the lumen of the central duct, and they extend far up the tubules toward the openings of the latter into the pericardial cavity. In one specimen blood plasma extends from the central duct two-thirds of the entire length of four or five tubules. The pericardial cavity communicates with the peritoneal cavity through the large pericardo-peritoneal foramen, and the peritoneal cavity opens into the cloaca through the genital pore, hence we have in Myxinoids the strange condition of the vascular system being open to the exterior of the body. The writer found no traces of blood in the pericardial cavity. Since there are many hundreds of tubules in each adult pronephros, it is difficult to explain why blood is not poured into the pericardial cavity. Price ('10) found that carmine grains injected into the peritoneal cavity through the genital pore of living animals were present later in abundance in the blood taken from different parts of the body. He presumed that the carmine grains gained admission to the blood stream through the ciliated pronephric tubules, that is to say any current in the tubules which is caused by ciliary action is from the exterior toward the interior. This inference is corroberated by the fact that in almost all the tubules examined by the writer the free ends of the granular processes extending from the epithelial cells of the tubules are directed inward toward the central duct.

In his description of the development of the pronephros Price ('04, p. 137) states that the manner in which the central duct becomes shortened as the tubules are crowded together is a point which has not been worked out; bending of the duct will not account for all of it. Kirkaldy ('94, p. 356) thinks the duct breaks down and becomes the central mass. Morphological evidence supports this hy-

pothesis somewhat. The diffused condition of the cells of the duct where the latter is in contact with the central mass suggests that the duct is breaking down, and the enlarged nuclei in the mass which are without granules are suggestive of disintegrating cells, while the rounded masses of small nuclei and granules found in the lumen of the duct may be interpreted as nuclei that have been broken down. These may either be ejected into the body cavity through the tubules and pericardial cavity, or, what is more probable, they may be swept into the blood stream and be engulfed by leucocytes. These masses occur only in or near the openings in the central mass which connect the central duct with the pronephric vein. In one specimen, however, a small ball of these nuclei was observed in a tubule. Furthermore, in those pronephroi in which the central duct is most continuous there is no central mass in the anterior part of the duct where its columnar walls remain entire, but the mass is limited to the posterior region where the walls of the duct have lost their columnar structure and the lumen of the duct is surrounded by the mass of nuclei. Also, in those specimens in which the duct is broken up into segments and the palisade wall has broken down, each segment, anterior as well as posterior, is surrounded by the central mass, but even in these specimens the bulk of the central mass is found at the posterior end of the pronephros, where the crowding of the original tubules is the greatest. On the other hand, the quantity of the central mass in the older animals seems greater than would be the case if it were all derived from merely a crowding-together of the central duct, especially if it were disintegrating all the while.

The central mass is the same in appearance and structure wherever it occurs in Bdellostoma stouti. No lymphatic tissue such as

Weldon ('84) describes is present at the posterior end of the pronephros of Bdellostoma stouti, unless he refers to the central mass around the duct.

The pronephros of Myxine differs strikingly from that of Bdellostoma in the fact that it contains much more connective tissue. The pericardial sheath around the tubules is farther from the wall of the tubule than in Bdellostoma, and the intervening space is usually filled with connective tissue. Also, there is much more connective tissue at the base of the pronephros, separating the latter from the pronephric vein, than in Bdellostoma, and bands of connective tissue even extend into the vein and into the central mass. In the older animals there is often considerable connective tissue between the walls of the tubule and the surrounding sheath of pericardium (figs. 23 and 24). The pericardial sheath is heavier and its nuclei larger than in Bdellostoma. Figure 25, a cross section of one lobe of a pronephros of an adult female, shows the proportion of connective tissue with reference to the size of the tubules which it surrounds. Not all the tubules in the pronephroi of this animal, however, have connective tissue between their walls and the pericardial sheath. In the youngest specimen examined, a young female 31 cm. long (#18), there is very little and often no connective tissue at all near the distal ends of the tubules. In the oldest specimen (Myxine #10) the connective tissue around the tubules and in the entire pronephros is more abundant than in any of the other animals and contains many blood vessels. In this specimen there is in transverse section of almost every large tubule a single large vessel which partially or entirely surrounds it.(fig. 26). A blood sinus which completely fills the space between the tubules, as is frequent in Bdellostoma, is rare

in Myxine. The blood around the tubules is almost always confined in vessels which lie in the connective tissue surrounding the tubules.

Unlike Bdellostoma, the tubules in an adult Myxine are not all of the same size (fig. 27). They are practically of the same size in the youngest specimen examined (Myxine #18), but in the older animals there is a gradually increasing number of tubules which are slightly larger than others, and in the oldest specimen (Myxine #10) there are present in the pronephros tubules which range in size from the smallest to very large ones. In Myxine #18 the average dimensions of the tubules are: Width of lumen 0.0162 mm., width of each wall 0.0189, outside diameter 0.054 mm. Only a few of this size are present in the pronephros of Myxine #10, many approximating the following dimensions: Width of lumen 0.108 mm., width of each wall 0.027, outside diameter 0.1620 mm. One tubule in Myxine #10 is very large, the outside diameter being 0.675 x 1.1475 mm. before it breaks up into smaller branches. The smaller tubules have practically no connective tissue between the walls and the pericardial sheath, the medium size tubules a little, while the large ones usually have a comparatively large quantity of connective tissue around them. The smaller tubules have the appearance of being recent branches from the larger ones.

Kirkaldy ('94)states that in a Myxine with large eggs the tubules at the posterior end of the pronephros are entirely different from those of a Myxine without eggs in that the former are considerably degenerated. The writer is of the opinion that this degeneration of the tubules is not so much a matter of being with or without eggs as one of age. Kirkaldy does not state whether the animal without eggs was young or old. In all the pronephroi of Myxine examined

by the writer the inner ends of almost all the tubules have disintegrated, only occasionally is one found whose walls remain intact to its opening at the inner end. Only in the oldest specimen (Myxine #10), which does not have any eggs, are there tubules which have the appearance of degeneration. Some of the largest tubules alone are degenerating, and answer to the description given by Kirkaldy. The nuclei are enlarged here and there in the walls, while some of them are attenuated and almost fibrous, and connective tissue is replacing the palisade cells. These degenerating tubules are not numerous and are not limited to the posterior end of the pronephros. They are surrounded by many smaller tubules which give no evidence whatever of degeneration, but on the other hand look like recently formed branches. The cells of the latter are more uniform in size and shape, and stain more deeply than those of the large tubules.

One of the most striking differences between the pronephroi of Bdellostoma and Myxine is the fact that in the latter the disintegrating process of the interior has proceeded further than in the former. In Bdellostoma the inner ends of the tubules are always entire, while in Myxine they are seldom so. In places only dense lines of nuclei indicate where the inner ends of tubules have been, and these lines are always streaming toward a more or less large, loosely arranged mass of nuclei bordering or lying in the pronephric vein.

Investigators do not agree as to the existence of a central duct in the pronephros of Myxine. W. Müller and Kirkaldy affirm, while Semon, Spengel and Maas deny the presence of the duct. After studying the pronephros of Bdellostoma, it is inevitable for one to conclude that a central duct at one time existed and that fragments of it still exist in Myxine. It is not at all prominent and might

easily be overlooked except in a comparative study. Along the entire extent of the pronephros the inner ends of the tubules, as stated above, end as a loosely arranged mass of nuclei in which a cavity frequently appears (fig. 28). This cavity is the remains of the lumen of the central duct. In occasional places it opens into the lumen of the pronephric vein, and blood corpuscles are seen in it and in the tubules near it (fig. 29). Here and there the central duct is cut in longitudinal section and is then unmistakable (fig. 30). The youngest specimen (Myxine #18) shows the duct but imperfectly (fig. 31). Likewise, in the oldest animal examined (#10) the duct has almost entirely disappeared, the lumen being visible for only a short distance in the posterior part of the pronephros and having but a small piece of columnar wall (fig. 32). Extending along the wall of the vein next to the pronephros is a large number of heavily stained nuclei, which are interpreted as remains of the central mass, or in other words, remains of the central duct and the inner ends of the tubules. Waste particles, nuclei and granules, are occasionally seen in the lumen of the duct and in the tubules. The tubules are filled with a coagulum which is more or less drawn out into granular processes, and these are almost always directed inwards. In only a few places do the walls of the duct still remain entire (fig. 33). Where the duct has entirely disappeared the tubules often border directly on the vein and their inner ends are degenerated.

The central mass in the pronephros of Myxine is decidedly different from that in Bdellostoma. In the young, immature animals (Myxine #18) it approaches in structure and appearance the condition existing in Bdellostoma (fig. 34). Here the mass contains the more or less oval nuclei, no blood corpuscles, but the cytoplasmic ground-

work is replaced by connective tissue. Also, one side of the mass projects into the lumen of the pronephric vein and has a more or less rounded form, while the other side remains attached to the base of the pronephros but is not as compact as in Bdellostoma. The mass is distributed along the entire length of the vein from the anterior to the posterior end of the pronephros, and extends behind the posterior end of the latter about 0.18 mm. in one specimen. This posterior extension of the mass is cylindrical, has a tubule which ends blindly in it, and contains several large blood corpuscles in capillaries.

In the older animals the central mass is much more unlike that of Bdellostoma. In the anterior part of the pronephros it consists of a loose collection of nuclei which extends along the base of the tubules, embracing their inner ends, either lying outside the vein or projecting slightly into it. The mass is not at all compact, and has no definite form. Many of the nuclei are distributed in an irregular manner along the sides of the vein. At the base of the pronephros the mass is more or less exposed to the blood in the vein, even though it does not project into the lumen of the latter. In occasional places the lumen of the vein opens through the mass (fig. 32) and communicates with the lumen of the central duct, and here blood corpuscles are present in the duct, but are rarely found in the tubules. In the posterior part of the pronephros the central mass becomes cylindrical and compact, and projects into and extends posteriorly in the lumen of the vein,completely surrounded by blood. It is bound to the sides of the vein by broad bands of connective tissue which extend from the side of the mass here and there (fig. 35). Blood vessels run from the connective tissue at the base of the pronephros into these bands of connective tissue. The fibers of the

latter continue to the center of the cylindrical mass, and enlarged nuclei and blood capillaries are arranged in a cellular structure around this central core of fibers. The giant blood corpuscles are rounded in shape and are contained in capillaries. They are very numerous in the central mass in Myxine, as many as fifteen in one section taken at random, and average 0.0081 mm. in diameter. Besides the giant corpuscles, there are many large nuclei in the central mass which are stained about the same as the nuclei of the tubules and which contain very many small granules. The giant blood corpuscles resemble those in Bdellostoma, but in the latter animal they are not nearly as numerous as in Myxine. In this posterior region of the pronephros of Myxine the central mass resembles a lymphatic structure.

Another striking difference between the pronephros of Myxine and that of Bdellostoma is the presence of broad bands of connective tissue which extend across the lumen of the pronephric vein from side to side and partially or completely divide the lumen longitudinally in two parts (fig. 36) These bands are present in all the pronephroi of Myxine, from the youngest to the oldest, and are not confined to any particular region of the pronephros. In one place near the Malpighian body of the pronephros a large, isolated, thick-walled duct begins blindly in such a band, continues in it for 16 sections and ends blindly. This duct has on one side the columnar cells characteristic of the central duct, on the other the appearance of a Malpighian body. From its posterior end a small tubule is given off which extends alongside the duct for five section then ends blindly. The entire structure measures 0.24 mm. long x 0.195 mm. wide. In another Myxine a similar duct arises in one of these bands of connective tissue, extends posteriorly in it for 24 sections (0.36 mm.) and

ends blindly at the side of a structure represented in figure 38, without connecting with a tubule which extends from the posterior end of the latter. These structures in the bands of connective tissue are interpreted as degenerating Malpighian bodies. Bowman's capsule is still present, and the tubules are connected with this, but the glomerulus is almost entirely gone.

Malpighian Body of the Pronephros

At least one Malpighian body is always found lying beside the posterior end of the pronephros of Bdellostoma and Myxine. Investigators of the headkidney of Myxinoids differ as to what part of the excretory system this Malpighian body belongs. W. Müller's figure 2 shows two of them in the pronephros. He failed to state directly whether he thought they belong to the pronephros or to the mesonephros. Kirkaldy seems to consider the Malpighian body as belonging to the headkidney. Semon ('96) thinks it is the first Malpighian body of the mesonephros. Spengel ('97) is of the opinion that this is in fact the glomus of the pronephros in Myxine. From his investigation of very young Myxine Maas ('97) concludes that it is the glomus of the pronephros formed by the 'concentriren' of the most posterior 'Gefässnetze' which surround the original segmental pronephric tubules. Price ('04, '10) regards this Malpighian body in Bdellostoma as belonging to the 'pronephros', and from embryological study concludes that it arises by the fusion of glomeruli which are formed in connection with some of the most posterior original tubules of the pronephros before they are crowded together by the posterior movement of the gills. Since in the embryo only two or three of the original tubules which take part in the formation of the head-kidney have glomerulii, then the definitive pronephros represents the fusion of not more than

two or three glomeruli.

The adult condition of the Malpighian body in Myxine and Bdellostoma supports the conclusions of Maas and Price in regard to the manner in which it is formed. The pronephros of both shows evidence of being the result of fusion of two or three glomeruli. The following description is for both Bdellostoma and Myxine, and any variations which either shows will be noted.

The Malpighian body is always located beside the posterior half of the pronephros, usually at the extreme posterior end. It is always imbedded in the connective tissue beside the pronephric vein and separated from the pronephros by the sheath of its Bowman's capsule and the pericardium, as well as by a more or less wide strip of the pericardial cavity (fig. 39). Quite frequently the Malpighian body is followed immediately by a second, the anterior end of which may lie beside the last few tubules of the pronephros (fig. 12). Ordinarily, however, this second Malpighian body is located back of the posterior limits of the pronephros. The capsules of the two Malpighian bodies shown in figure 12 are connected by a very narrow duct, the short columnar cells of which do not have as much cytoplasm as those of the pronephric tubules and absorb much stain. The second Malpighian body is interpreted as being the first Malpighian body of the mesonephros. It is connected by a tubule to a short piece of the segmental mesonephric duct which lies in the lumen of the pronephric vein. The vein ends blindly with this piece of the mesonephric duct a few sections posterior to the Malpighian body. Furthermore, two pronephric tubules, which open into the capsule of the Malpighian body of the pronephros extend into the pronephric vein, unite and enter the piece of mesonephric duct. Surrounding the base

of these tubules just before they enter the mesonephric duct is a small amount of the central mass. This short piece of duct contains waste particles throughout its entire extent. The continuous duct of the mesonephros in this specimen begins five millimeters posterior to this short piece and there is no connection whatever between them. When there is but one Malpighian body it usually ends blindly, although the capsule may be drawn out posteriorly into the very small duct which ends in the connective tissue.

In shape the Malpighian body of the pronephros of both Bdellostoma and Myxine is usually an elongated oval, although it may be almost round or flattened somewhat laterally. In Myxine one end is, as a rule, more pointed than the other.

The glomerulus of the Malpighian body in Bdellostoma is comparatively compact and uniform in structure. The surface is smooth but slightly convoluted, and is covered by the epithelial lining of Bowman's capsule. There are lines of division which separate the glomerulus here and there into lobes (fig. 40), and in almost every specimen are one or more small cavities inside of which are blood corpuscles or blood plasma. In appearance the glomerulus of the youngest Myxine (#18) is very similar to that of Bdellostoma. In the older specimens, however, the lobed condition is more apparent, it is much less compact and has a more or less shriveled appearance, and the spaces in the glomerular mass are more numerous and larger. Webs and strands of connective tissue appear everywhere in the glomerulus and around the outside of the lining of Bowman's capsule. In the oldest Myxine (#10) these changes are most advanced (fig. 41). As this figure shows, one large blood sinus has appeared in the glomerulus. This sinus contains corpuscles and blood plasma, and extends

almost the entire length of the glomerulus. It has an epithelial lining, outside of which are several concentric layers of connective tissue. On the opposite side of the glomerulus there is a large space with comparatively few nuclei, but entirely filled with slender fibers of connective tissue. This space also extends almost the entire length of the glomerulus. The lining of Bowman's capsule is an epithelium surrounded by a broad band which consists of concentric layers of connective tissue.

In one Bdellostoma and one young Myxine the glomerulus of the pronephros is double; two distinct glomerular masses are contained in the same Bowman's capsule. In the Bdellostoma the capsule is constricted to one-half its width at the point of union between the two glomerular masses, while in the young Myxine there is but a slight constriction in one side of the capsule (fig. 42).

In all the pronephroi of both animals one or more pronephric tubules open into the cavity of Bowman's capsule of the Malpighian body. The capsule in every specimen of Bdellostoma is connected with the pericardial cavity by a more or less long, very narrow duct (approximately one-half as wide as a pronephric tubule). In addition to this duct there may be one or more very small openings through the wall of the capsule which connect the cavity of the latter with the pericardial cavity. The capsule of the specimen represented by figure 12 has seven such openings. In none of the specimens of Bdellostoma are these openings into the pericardial cavity greater than two or three one-hundredths of a millimeter in diameter.

Spengel ('97) considers the glomerulus of the pronephros to be really a glomus because it hangs freely in a cavity which he found communicated with the pericardial cavity through a very large aperture; in one specimen the opening extended through nineteen sections

each 30 microns thick, or 0.57 mm. Semon ('97) never saw in his preparations a communication as wide as Spengel describes. Maas ('97) also considers the glomerulus a true glomus. In each of his youngest Myxine he found a very large opening connecting the capsule with the pericardial cavity; it extended through almost as many sections as the glomus itself. But in advanced stages, by a folding of the epithelial wall, a capsule is formed around the glomus and only a slit-like communication with the pericardial cavity is left, and even this may be completely closed. The glomerulus of the youngest Myxine examined by the writer (#18) lies directly exposed to the pericardial cavity through an opening 0.156 x 0.192 mm. and resembles a glomus (fig. 43). The opening in Myxine #15, an adult, measures 0.0195 x 0.105 mm., and that of Myxine #10, the oldest specimen, is 0.195 x 0.120 mm.

The glomerulus of the head-kidney is not always as large in comparison with the glomeruli of the mesonephros as would be expected if it were formed by the fusion of two or three glomeruli, as the following measurements will indicate:

Specimen	Side	Glomerulus	Width	Length
Bdell. #4	Right	#1	0.46	0.78 mm.
		#2	0.34	0.75
		#3	0.60	1.04
		4#	0.48	0.92
	Left	#1	0.50	0.95
		#2	0.39	0.65
		#3	0.49	1.03
		#4	0.47	0.785
Bdell. #6	Right	#1	0.39	0.66
		#2	0.4485	0.60
		#3	0.468	0.66
	Left	#1	0.390	0.675
		#2	0.4485	0.705
		#3	0.30	0.4875
Bdell. #10	Right	#1	0.41	0.60
		#2	0.27	0.2925
		#3	0.2925	0.405
		#4	0.41	0.60
Bdell. #15	Right	#1	0.39	1.10
		#2	0.40	0.30
		#3	0.40	0.50
		#4	0.65	0.65
	Left	#1	0.4485	0.88
		#2	0.39	0.40
		#3	0.40	0.60
		#4	0.53	0.84
Bdell. #16	Left	#1	0.41	0.60
		#2	0.2925	0.45
		#3	0.2925	0.45
		#4	0.39	0.51
Myxine #10	Right	#1	1.2675	1.305
Myxine #11	Left	#1	0.8775	0.975
Myxine #15	"	#1	0.6825	0.84
Myxine #18	"	#1	0.4095	0.348

The figures #1, #2, #3, #4 in the column under "Glomerulus" represent the number of the glomerulus, counting that of the head-kidney as #1; glomeruli #2, #3, and #4 are the first, second and third glomeruli, respectively, of the mesonephros immediately following the glomerulus of the pronephros. All the glomeruli which lie

posterior to the glomerulus of the pronephros are considered as belonging to the mesonephros. The glomeruli of the latter gradually diminish in size posterior to the most anterior three or four. None of the anterior glomeruli of the mesonephros of Myxine were sectioned, therefore no measurements of these are given in the above table. As the table shows, the glomerulus of the pronephros does not always exceed or even equal in size some of the most anterior glomeruli of the mesonephros.

As has already been noted, the Malpighian body of the pronephros of one Bdellostoma (fig. 12) is connected by tubules to a fragment of the segmental duct of the mesonephros which is entirely disconnected from the continuous part of the duct. No other case of a communication between the Malpighian body of the pronephros and the duct of the mesonephros was found in either Bdellostoma or Myxine. In a young male Bdellostoma (#22), however, the mesonephric duct on each side continues to the posterior end of the pronephros, as is shown in figures 1 and 2. When the anterior ends of the ducts of this animal were sectioned it was found that the lumen of the right duct ends beside the posterior end of the Bowman's capsule of the Malpighian body of the pronephros, but there is no communication between them. Some of the sections of the left duct were scraped off the slide in this region, hence the duct could not be followed. Immediately posterior to the pronephros the lumen of the right duct of this animal abruptly enlarges, becoming a cavity which measures 0.4875 x 0.6240 x 1.335 mm. This cavity is almost entirely filled with a rounded, loose mass of nuclei which resembles a disintegrating glomerulus. This mass is connected here and there to the lining of the duct by narrow strands of nuclei, but no blood vessels could be seen in them. The lining of

the duct here does not resemble that of a Bowman's capsule, and is composed of short columnar cells like those of the pronephric tubules. If this be a disintegrating glomerulus, it is difficult to explain why it should be in the lumen of the mesonephric duct. Immediately posterior to this enlarged cavity the duct becomes narrowed to a diameter of 0.117 mm.

MESONEPHROS

Bdellostoma

Mesonephric Ducts

Excepting in specimen #22, the mesonephric ducts of the Bdellostoma examined begin from two to ten millimeters back of the posterior end of the pronephros. Small strands of tissue, resembling in structure the outer wall of the duct, extend from the anterior end of the duct toward the pronephros. Sometimes a lumen is present in one of these strands for a varying but short distance. These strands may be the only trace of pro- or mesonephric elements between the posterior limit of the pronephros and the anterior end of the ducts, or, in addition to these, there may be one or more isolated tubules or traces of glomeruli in this intermediate region.

The anterior ends of the right and left ducts in an individual animal are seldom opposite each other. The duct does not start abruptly, but is always narrowest at the anterior end, and presents the appearance of having at one time extended farther forward. There is no uniformity in the diameter of the duct at its anterior end, except that it is always smallest here, varying in width from a mere thread to one millimeter.

The left duct usually bends abruptly laterad at its anterior end until it assumes a position close beside the left postcardinal vein, and retains this position to the end of the body cavity. The

right duct bends only slightly laterad at its anterior end to assume a similar position beside the right postcardinal vein. The right duct is invariably closer to the dorsal aorta than the left.

In adults of the same size, the ducts of the males are larger and longer than those of the females. There is not much variation in the size of the two ducts of a given animal, nor in the ducts of all the adult animals of the same sex. Each duct is smallest at its anterior end, and gradually increases to its largest size at the posterior end of the body cavity, where it is from 1½ to 2 mm. wide in females and from 3½ to 4 mm. in males.

Each duct is flattened dorso-ventrally throughout its entire length, being most flattened at the posterior end of the body cavity. The outer surface of the ducts is smooth. When a duct is stained, cleared and examined under the microscope the surface appears to be longitudinally striated, due to the occurence of ridges formed in the lumen of the duct by the columnar epithelial lining.

The ducts lie immediately ventral to the notochord, separated from the latter by a small cavity which extends the entire length of the ducts. By cutting the peritoneum along the dorsal body wall at the sides of each duct, the ducts together with the postcardinals and the dorsal aorta can easily be removed. The epithelium of the peritoneum extends along the ventral surface of the two ducts and the two postcardinals and the dorsal aorta, while the mesodermic part of the peritoneum splits when it meets the ducts, a narrow band of it extending along the ventral surface of the ducts with the epithelium, while the greater portion of it runs along the dorsal surface of the ducts and the three blood vessels (fig. 44). Thus, the ducts, the two postcardinals and the dorsal aorta are in a sheath of the meso-

dermic portion of the peritoneum, but lie dorsal to the epithelium which lines the body cavity.

The mesonephric ducts of the adult male are unlike those of the adult female in some respects. Those of the former are not only larger, but are longer by reason of lateral bendings or convolutions. Figure 45, a dorsal view, represents the typical appearance of the male ducts, and figure 46 those of the female. At their anterior ends the ducts of the male are but slightly convoluted, but beginning about ten somites posterior to the anterior ends the convolutions become quite pronounced and regular. There is but one convolution in each somite: the ducts bend laterad at the interseptal lines and mediad between these lines. The convolutions continue to the posterior end of the body cavity, but in the last five or six somites they diminish in extent. The greater size of the male duct is caused principally by the fact that its lumen is larger than that of the female. The walls of the male duct, however, are somewhat coarser than those of the female duct.

No such convolutions occur in the ducts of the females. The ducts bend laterad more or less slightly at the interseptal lines, but there is no suggestion of the convoluted condition of the male ducts.

At their posterior ends, the ducts of both males and females have the same gross structure and appearance. The two ducts leave the peritoneal cavity at its posterior end, approach each other and continue a short distance (5 to 10 mm.) along the dorsal surface of the genital chamber, then converge sharply. At the point of convergence the ducts bend ventrad and laterad, and become abruptly narrowed to very small tubes (figs. 47 and 48). The latter continue

posteriorly, bend sharply ventrad at the posterior end of the cloaca, and open in this region of the cloaca on a papillary enlargement in a prominent ridge which extends along the dorsal wall of the genital chamber and cloaca. The two openings lie alongside, but one is usually slightly posterior to the other.

The ducts of young males (fig. 49) are not convoluted at any place, and resemble in appearance and gross structure those of adult females.

Histology

Figures 50 and 51 are camera lucida drawings of transverse sections of a male and female duct, respectively, taken from the mid-region of the body cavity. The section of the male duct was selected where there is the smallest possible effect on the internal structure because of convolution. As the figures show, the ducts consist of an inner epithelium and an outer envelope of connective tissue.

The epithelium is composed of columnar cells, and is arranged in a series of longitudinal folds or ridges. Wax models show that these ridges branch and anastomose freely, but are always longitudinal and the branching is dichotomous. The two branches may run parallel to each other for a short distance then unite, or may unite with another ridge, or may end without union to other ridges. A ridge may be only a fraction of a millimeter long and be entirely unattached to any other ridges. When free, the ends of the ridges rise gradually from the normal height of the epithelium.

The ridges are present in all parts of the duct from the anterior to the posterior end, but at the former end where the duct is small they may be only two or three in number (fig. 52). As the

duct becomes larger, the ridges increase in number, and are most numerous at the posterior end where the duct reaches its maximum width. The ridges vary in number in a transverse section in corresponding regions in different adult specimens, as is indicated by the following table:

Specimen	Outside diameter of duct	Number of ridges	Highest ridges
Bdell. #15, female	0.546 x 1.0725	20	0.1365
" #17, "	0.351 x 1.365	29	0.0780
" #16, male	0.780 x 2.4375	26	0.390

There is considerable variation in the height of the ridges in the same transverse section and in different parts of the same duct. Figures 50 and 51 show the variation in the same section. For a given duct the ridges are lower at the ends than in the mid-region.

The columnar epithelial cells which form the walls of the duct are shortest between the ridges. The nucleus is always located about one-third the length of the cell from the basal membrane. The cytoplasm is very granular throughout the entire cell body, the granules being especially numerous and large at the distal ends of the cells. Along the surface of the distal ends of the cells are agglutinations of granules which project into the lumen of the duct and resemble the mass of waste material which is seen in the center of the lumen of the duct throughout its entire length. Toward the distal ends of the cells are numerous small and large, yellowish, round or oval bodies of homogeneous structure which resemble oil droplets. Some of these are minute granules, while others are as large as the nucleus of the cell. They are especially numerous and large in the cells on top of the ridges, and are distributed in no definite manner. Only a few are found in the cells between ridges. These bodies are probably what W. Müller described as yellowish pigment granules. The larger bodies do not resemble pigment granules, however.

The long, columnar cells are always arranged on the ridges in the shape of a fan, as illustrated in figure 53. To form a ridge, the entire layer of epithelial cells bends into the lumen of the duct, and the connective tissue outside the basal membrane of the epithelium makes a core which fills the concavity beneath each ridge (fig. 53).

The ridges are more numerous in the adult male ducts than in the adult female. They are also higher, but the cells are no longer than those of the female. The greater height is due to the fact that the epithelial layer extends farther into the lumen of the duct in the males. Wide ridges are more numerous in the male than in the female, some of them being flat on top. The concavities formed by the infoldings of the epithelial layers are larger in the male than in the female, and are also filled by a core of connective tissue.

Maas ('97) has suggested that the mesonephric ducts are not simply excretory ducts, but they may have a secretive function as well. The distribution of the blood vessels, the presence of cilia, the folded epithelium, the enlarged condition of the ducts in comparison to the small tubules of the Malpighian bodies of the mesonephros have been mentioned in the literature as indicative of such a possibility. The many large foldings or ridges or epithelium certainly increase the epithelial surface far beyond what would seem necessary for excretion alone. The enlarged, convoluted condition of the ducts in the males is very peculiar. The presence of the small and very large, yellowish bodies near the distal ends of the epithelial cells, especially in the large cells of the ridges, is suggestive of secretion.

The envelope of connective tissue surrounding the duct consists

of two parts, a loose web containing blood vessels and a more or less compact stratified layer. The loose web lies next to the basal membrane of the epithelium. It follows closely the outline of this membrane, and fills the concavities under the ridges, as shown in figure 53. Some of the blood vessels in this connective tissue contain giant blood corpuscles such as those found in the central mass.

The compact stratified layer consists of fibers arranged in concentric rings around the duct, and is usually thicker along the median surface of the duct. The peritoneum lies next to the stratified layer.

The writer was unable to identify in Bdellostoma the three layers which W. Müller describes as forming the connective tissue envelope around the duct of Myxine. Nowhere is there a layer that can be called the 'membrana propria'. The two layers observed by the writer correspond to the 'adventitia' and the layer which contains blood vessels, as designated by Müller.

Malpighian Bodies

Price has shown that at one time in the development of Bdellostoma the mesonephric duct is continuous with the central duct of the pronephros, but that later a short piece of the duct posterior to the pronephros degenerates, together with its Malpighian bodies. The amount which degenerates is not always the same, hence in the adult there is considerable variety in the structure of the anterior ends of the ducts and in the location of the first few Malpighian bodies of the mesonephros. The most anterior Malpighian body of the mesonephros may be located immediately posterior to the Malpighian body of the headkidney and be attached to the latter and to a short, isolated piece of the mesonephric duct (fig. 12). Or it may be completely

isolated in the space between pro- and mesonephros. Not only one, but two or three of the mesonephric Malpighian bodies may be in the intermediate space entirely disconnected from each other and from the mesonephric duct. Again, the first Malpighian body of the mesonephros may be located at the anterior end of the duct, and its tubule may be widened to form the beginning of the duct, or the latter may extend slightly anterior to the Malpighian body, in which case the tubule enters the lumen of the duct at the side. Two or three Malpighian bodies may be crowded close together around the anterior end of the duct, but their tubules always enter the lumen of the duct separately and in consecutive order (fig, 54). This figure is a drawing of the anterior ends of the ducts of Bdellostoma #4. On the left side Malpighian bodies #1, #2, and #3 are very close together. The first two are in one somite, #3 occupying the next segment. When the Malpighian bodies are thus crowded together at the anterior end of the duct the arteries which supply them arise from the aorta at successive points close to the posterior end of the pronephros, a condition which suggests that these Malpighian bodies have been pushed back from a more anterior location. For example, the point of origin of the artery which supplies the first Malpighian body of the right duct of Bdellostoma #15 is 3.5 mm. anterior to the Malpighian body, and the latter is only 5 mm. posterior to the caudal end of the pronephros.

Except where the Malpighian bodies are occasionally crowded together at the anterior end of the duct, there is but one in each somite to somite 60--65. The ducts usually begin in somite 33--35, and the body cavity extends to somite 75--79, hence the posterior third of the ducts have no Malpighian bodies. Price learned that in embryos excretory

is supplied by a branch from the same somatic artery, the anterior one is doubled back upon its tubule so the distal end points posteriad toward the origin of the artery which supplies it.

Each Malpighian body has a tubule which enters the mesonephric duct. There are two types of these tubules which differ distinctly and which will be designated as 'plain' and 'compound' tubules. All the tubules of a given animal are of one type only.

The plain tubules are composed of very short, columnar cells which have very little cytoplasm, as shown in figure 57. These cells are all approximately the same size. Their nuclei stain much more deeply than either the nuclei of the connective tissue or those of the mesonephric duct, hence the tubules are very distinctly differentiated from surrounding tissues. At the proximal end the cells of the tubule are directly continuous with those of the mesonephric duct, and at the distal end with the cells of the single layer of squamous epithelium which lines Bowman's capsule. The basal membrane of the mesonephric duct is continuous with that of the tubule. The tubules vary in length, the shortest averaging 0.07 mm., the longest 0.2 mm. When long, they are more constricted than when short, the outside diameter of the narrowest tubule measured being 0.04 mm. The size of the opening where the tubules enter the duct varies, but approximates 0.12 mm. in diameter. Figure 58 is a diagrammatic reconstruction of a plain tubule.

The compound tubule is strikingly different from the plain, as is shown by figure 59, which is a reconstruction of a Malpighian body with a tubule of this type. It consists of two parts, a neck and a base. All of the Malpighian bodies of all the specimens examined, except the one described above, have this type of tubule. The neck is that part of the tubule which joins the Bowman's capsule, and in

tubules are present in the most posterior somites, but they later degenerate in the last 19 or 20 segments. The most posterior Malpighian bodies in the adult show signs of degeneration. They are small, often not visible to the unaided eye, frequently in a shriveled condition, and parts of them may be lacking; for example, in one case the tubules only is present. This degeneration is of unequal extent in different animals and on both sides of the same animal.

Except an occasional one at the anterior end, all the Malpighian bodies lie along the median side of the duct. There is no regularity in the orientation of the bodies with reference to the somites; they may be located at either anterior or posterior side or near the middle of the somite. Those of a side are not separated from each other by equal intervals, but as a rule are arranged in poirs, a greater distance occurring between two pairs then between the two bodies of a pair (figs.55 and 56). This paired condition is in some way connected with the arterial supply, as is shown by figure 56. Each of the Malpighian bodies represented in this figure is in a separate somite. The two arteries which supply the two Malpighian bodies of one of these pairs are usually branches from a somatic artery, as shown by figure 56, but sometimes one of the arteries arises directly from the dorsal aorta, close beside the somatic artery. When a Malpighian body is not one of a pair, its artery comes directly from the dorsal aorta. Seldom are the two Malpighian bodies of corresponding somites on each side of the body opposite each other, as is shown by figure 55.

The Malpighian bodies and their tubules usually extend anteriorly from the point where the tubule empties into the mesonephric duct. When, however, each Malpighian body in two adjacent somites

structure and appearance it is exactly like the plain tubules. It consists of short, columnar cells of approximately equal height and which have very little cytoplasm. The nuclei stain much more deeply than those of surrounding tissues, so that the eipthelium of the neck is easily distinguished from that of the base. The cells of the neck gradually decrease in height as they approach Bowman's capsule, and are continuous with the cells of the single layer of squamous epithelium which lines the capsule. The neck is variable in width and length within narrow limits in different specimens and in different tubules of the same specimen. An idea of the dimensions may be had from one specimen: Outside diameter at entrance to base of tubule, 0.35 mm., and at entrance to capsule, 0.078 mm; length, 0.4 mm. The neck is sometimes as much as twice this length, however. At the proximal end of the neck its epithelial cells and basal membrane are continuous with the cells and basal membrane, respectively, of the base of the tubule. The transition from the cells of the neck to those of the base is gradual, as shown in figure 60.

The base of the compound tubule is exactly like the mesonephric duct in structure. It consists of an epithelium of high columnar cells which are arranged in ridges, and cells and ridges are of approximately the same height as those of the duct. At the anterior end of the duct this portion of the tubule is often as large in diameter as the duct itself. Farther posteriorly, however, where the duct is larger the base of the tubules is only from one-fourth to one-third as large as the duct. At the opening of the base of the tubule into the duct the epithelial cells of both are continuous with each other, including their basal membranes (fig. 61). When the base of the tubule lies close beside the duct, each has its own en-

velope of connective tissue, but the two are bound together by a compact band of connective tissue arranged in concentric layers. The base of the compound tubules varies somewhat in length, but is not more than a fraction of a millimeter, approximating 0.75 mm. The base and neck together are about 1.5 mm. long. In some cases the neck may be longer than the base, but it is usually much shorter.

Waste granules resembling those in the duct are present in large quantity in the lumen of both the plain and compound tubules along their entire length. The short columnar cells of the plain tubules and of the necks of the convoluted tubules lack the yellowish bodies which are found in the cells of the duct, but the long columnar cells of the base of the compound tubules have more or less of them.

Each glomerulus almost entirely fills its Bowman's capsule. The squamous epithelial lining of the capsule continues around the glomerular mass. The capsule is usually oval in shape. The glomeruli are usually largest at the anterior end of the duct, and diminish in size gradually toward the posterior, the most posterior being the smallest. For instance, the following are measurements of glomeruli from different regions of the duct:

Region	Side	Width	Length
Anterior	Right	0.640	0.680 mm.
	Left	0.600	0.830
Middle	Right	0.500	0.630
	Left	0.480	0.645
Posterior	Right	0.345	0.351
	Left	0.331	0.405

The tubules of the Malpighian bodies, also, are smallest and shortest at the posterior ends of the duct. In one specimen the most posterior trace of a Malpighian body is a compound tubule the base of

which opens into the duct, and the neck ends blindly. The neck is 0.06 mm. long x 0.105 mm. wide, and the base is 0.15 mm. long x 0.21 mm. wide.

Each Malpighian body is surrounded by a compact stratified connective tissue band which is arranged in concentric rings and which is closely applied to the epithelium of the capsule. Outside this band of connective tissue there may be a more or less loose web of connective tissue which envelopes the Malpighian body and the mesonephric duct. In one section which shows the short plain tubule opening into both the duct and the capsule the broad band of stratified connective tissue surrounding the duct continues around the tubule and the Bowman's capsule. Here the tubule is very short and narrow. Figure 62 shows the relation of these tissues when both glomerulus and the basal portion of the tubule are present in the same section with the duct. From this figure it will be observed that the glomerulus and the distal end of the tubule are not entirely separated from the mesonephric duct, but that they are bound to the latter by either a band or a web of connective tissue which envelopes both duct and Malpighian body.

Myxine

Mesonephric Ducts

The mesonephric ducts of Myxine are like those of Bdellostoma in so many respects that a detailed description of them would be needless repitition, hence only points in which they differ will be noted.

The ducts are longer in Myxine, of course, and are a fraction of a millimeter narrower than the female ducts of Bdellostoma. The ducts of the latter are gray and opaque, while those of Myxine are approximately of the same color as the flesh and are somewhat transpar-

ent.

The anterior ends of the ducts are farther removed from the pronephros in Myxine, being 10 to 20 mm. posterior to it. No bendings or convolutions were present in the ducts of any of the specimens. The laterad bending at the interseptal lines is somewhat less than in Bdellostoma, which may be due to the fact that the somites are larger in Myxine. In the adult Bdellostoma the somites are approximately 5 mm. wide, while in Myxine they are about 6½ mm.

The histology of the ducts of Myxine is practically the same as those of Bdellostoma. The long columnar cells are arranged in longitudinal ridges. In the youngest specimen studied (Myxine #18) the ridges are not formed in the same manner as in Bdellostoma. The basal membrane of the epithelium does not bend inward, toward the lumen of the duct, at the base of the ridges, hence no concavities are formed under the latter. Also, the nuclei of the epithelial cells remain at the same level around the entire circumference of the duct and turn inward only very slightly at the base of the ridges. The ridges are formed solely by the elongation of the epithelial cells. The longest cells are approximately 0.0675 x 0.0081 mm. The majority of the nuclei are round, although many are short ovals. There are approximately fifteen ridges in each duct in the mid-region of the body.

In all the adult Myxines the ridges in the ducts are more numerous, shorter and narrower than in Bdellostoma. Their shape is slightly different from those of the latter animal, and much more uniform. They are usually narrower in the middle than at the ends, and never have a wide, flat surface such as are frequent in Bdellostoma. In one specimen which has eggs 12 mm. long the duct is 0.39 x 1.2675 mm., and has 54 ridges each approximatly 0.039 x 0.117

mm. The duct of another animal measures at one place in the mid-region selected at random 0.2925 x 0.975 mm., and has 53 ridges, each approximately 0.029 x 0.105 mm. The ridges present a finger-like appearance, as shown in figure 63.

The epithelial ridges in the ducts of adult animals do not have concavities beneath them, but the nuclei at the base of the ridges are arranged in a small heap (fig. 63).

The nuclei of the epithelial cells in the ducts of Myxine are much nearer the bases of the cells than in Bdellostoma. Most of them are round, but some are oval. All the cells have much cytoplasm, and as a rule they are narrower at the middle than at the ends.

A very striking difference between the epithelial cells of Myxine and those of Bdellostoma is the quantity and distribution of the yellowish bodies. These are present in every ridge in Myxine, more in some ridges than in others of the same section, and more in some sections than in others. They are almost entirely confined to the center of the ridge, forming a narrow core which extends from the nuclei at the base of the cells to the top of the ridge (fig. 64), but not to the very distal ends of the cells. At the top of the ridges these yellowish bodies are in rows which spread out in the shape of a fan, following the arrangement of the cells. The bodies vary in size from tiny granules to a diameter exceeding the width of a cell, and large and small are intermingled in an irregular manner in all parts of the core.

There is much less connective tissue around the mesonephric ducts and Malpighian bodies in Myxine than in Bdellostoma. The Malpighian bodies are confined to the anterior two-thrids of the duct, one in each somite. They are approximately the same size as those

of Bdellostoma, the largest at the anterior end of the ducts and the smallest toward the posterior. Only the compound type of tubules were found in Myxine, and these are usually shorter than the compound tubules of the Malpighian bodies in Bdellostoma.

2. Reproductive System

Myxine

Female

The following is a general description of the female generative apparatus in Myxine. It is not strictly applicable to any one specimen, for there is much variation within certain limits. Schreiner ('04) has given a very detailed account of the ovary in the European Myxine, and examination shows that the North-American Myxine does not present any striking differences.

The single ovary occurs on the right side, and extends from the region of the gall bladder to the posterior end of the coelomic cavity, and is approximately (within 2 or 3 centimeters) one-half the entire length of the animal. It is suspended in the body cavity by a single mesovarium which is attached along its proximal margin to the mesentery where the latter joins the dorsal surface of the alimentary canal, to the right of the supra-intestinal vein. In young animals the mesovarium presents a perfectly flat surface, but in specimens which have eggs 5 mm. long or more it becomes folded transversely, being most folded in the oldest females. The distal margin of the mesovarium does not take part in this folding, but remains straight, therefore the two margins are much shorter than the rest of the mesovarium, a condition which causes the mesovarium to bulge out laterally.

For about ten millimeters at the anterior and posterior ends, the mesovarium is merely a line along the dorsal surface of the di-

gestive tract then increases more or less abruptly to its average width. At the posterior end it decreases more or less gradually to a line on the dorsal surface of the alimentary canal, and ends at the genital pore. Even in the youngest females, where the mesovarium is simply a flat sheet, its width varies at different points along its course (fig. 65). In successive older stages these inequalities in width are more and more pronounced, the widest points being where the eggs are attached. In the youngest specimens (#18) the mesovarium is 2mm. wide at the widest points, and in Myxine #2, which has eggs 22 mm. long, it is as wide as 30 mm. where the large eggs are attached. Between these large eggs the mesovarium is from 10 to 20 mm. wide. The weight of the eggs doubtless stretches the mesovarium, for it is drawn out into an elongated strand where each egg is suspended. Frequently these strands are intertwined and even tied in knots. In specimen #20 the mesovarium is 25--30 mm. wide and the strands to which the corpora lutea are attached extend only three or four millimeters beyond the general width of the mesovarium. In one of the oldest females the mesovarium is approximately 15 mm. high along its entire course, except at the ends, and its distal margin is not folded, but is comparatively straight. Another old specimen has a mesovarium which is 20--25 mm. wide, and its distal margin is also straight. It is probable that after losing the eggs the distal margin of the mesovarium tends to become straight again and the excessive width caused by stretching where the eggs were suspended is taken up by much transverse folding. As stated above, the distal margin of the mesovarium does not take part in this folding.

Eggs

The eggs seldom occupy more than the distal third of the mes-

ovarium, never extending entirely to the proximal margin. In the adult animals they are distributed throughout the distal half of the mesovarium, even to the outermost margin, but in one of the young specimens (fig. 65) the most distal millimeter of the mesovarium is entirely without eggs.

The smallest eggs are always most distal, successively larger stages extending proximally, the largest being most proximal (fig. 66)

Lengthwise the eggs are comparatively evenly distributed along the mesovarium, except there are few, if any, in the most posterior 20--30 millimeters. Eggs larger than 10mm. long, when present, usually occur at fairly regular intervals along the mesovarium from within 2 to 5 centimeters of its anterior end to 3 to 10 centimeters from the posterior end. Often from three to four or five large eggs are found together in a cluster, due to the intertwining of the long strands of mesovarium by which they are suspended.

In each female that has normal eggs there are all gradations of sizes of these from mere dots to 2 mm. long. When eggs longer than 2 mm. are present there are no intermediate sizes between the 2 mm. eggs and the large ones, and the latter are within one or two millimeters of being the same size. The largest eggs found in any of the specimens measure 7-8 x 24-25 mm.

In immature females the smallest eggs are crowded close together along the entire distal margin of the mesovarium. In older specimens the smallest eggs are much less numerous; clusters of them are separated by more or less wide intervals. Eggs 2 mm. long average approximately one for every 5-10 mm. of mesovarium in young females, and even less in adults. The following table shows the number of larger eggs present in a few individuals:

Number of specimen	Length of animal	Size of eggs	Number of eggs
#16	50 cm.	$1\frac{1}{2}$-2 x 6-7 mm	37
#8	56 "	3-$3\frac{1}{2}$ x 10-11	35
#6	61	3-4 x 13-15	45
#4	61	6-7 x 18-19	33
#2	58	8-$8\frac{1}{2}$ x 19-20	27
#14	$58\frac{1}{2}$	7-8 x 21-22	28
#11	55	8-9 x 21-22	26
#3	64	7-8 x 24-25	35

None of the eggs are so far advanced as to have hooks at the ends.

In shape the eggs are round until they reach a diameter of about $1\frac{1}{2}$ mm., then they begin to elongate, and become oval. Eggs 2 mm. long are 1-$1\frac{1}{2}$ mm. wide. The eggs are developed between the two layers of peritoneum which form the mesovarium, as shown in figure 74. When the eggs begin to assume the oval shape, the pointed ends project beyond the place of attachment to the mesovarium, and one end evidently grows more rapidly than the other for the largest eggs are usually attached between one end and the equator, leaving the ends free (fig. 67).

Other structures besides eggs may be present in the mesovarium. Specimen #20 has 33 empty egg envelopes, the 'corpora lutea' (fig. 68). The largest eggs in this animal are approximately 1 x $1\frac{1}{2}$ mm. Specimen #2 has, besides the 27 large eggs, two corpora lutea, each of which is the same size as the envelopes around the eggs ($8\frac{1}{2}$ x 20 mm.), and which has been opened along one side (fig. 69). The corpora lutea in Myxine #20 are much smaller (4 x 6 mm.) and are shrunken into a compact mass. Myxine #5 has 25 or 30 of these corporea lutea which are still smaller (2 x 3 mm.) than those of specimen #20, as shown in figure 70. The largest eggs of specimen #5 are $1\frac{1}{2}$-2 x $\frac{1}{2}$-1 mm. Specimen #1 has several even smaller corpora lutea. The writer is unable to explain what is the final fate of the corpora

lutea, unless they form some of the small brown oval bodies which will be described later. It seems improbable that they are completely absorbed. The fact that, as noted above, there are no intermediate stages between eggs about 2 mm. long and the large ones, and that also in animals which have corpora lutea the eggs present do not exceed 2 mm., is interpreted to mean that as soon as some eggs exceed 2 mm. in length all the other eggs are arrested in development until the larger ones have matured and have been ejected from the body, and their corpora lutea are well along in the process of degeneration.

Distributed comparatively uniformly along the entire mesovarium, wherever eggs occur, are numerous brown oval bodies which measure approximately $\frac{1}{2}$ x 1 mm. They are somewhat flattened laterally, and are located proximally to the smallest eggs. None of these brown bodies are present in the youngest specimens, but they occur in all adult females, being most numerous in the older ones. In the mesovaria of some of the latter, for example specimen #9, there are no eggs, but many of these brown bodies. Since only comparatively a few eggs become larger than 2 mm., many eggs do not attain complete development, but degenerate. The brown bodies are the degenerated eggs and their envelopes. Intermediate stages of degeneration between the brown bodies and the normal eggs occur occasionally. It is possible that some of the brown bodies represent degenerated corpora lutea, though none were found whose structure would indicate this. As shown in figures 71, 72 and 73, representing sections of three stages of these, the mesovarium envelopes the brown bodies in the same manner as it does the small eggs (fig. 74), but the walls of the envelope areund the former are much thicker. Also, numerous blood capillaries occur between the envelope and the former membranes

of the egg, which have been converted into convoluted strands of connective tissue. The center of the brown bodies is filled with round nuclei and dark-yellowish granules which may be the remains of the yolk and which cause the brown color.

Along the posterior 25 or 30 mm. the mesovarium of young animals has a narrow band (½ mm. wide) of testis lobes, as shown in figure 65, but there are no traces of such testis lobes in any of the nine adult females which have normal eggs. A few small eggs are occasionally found in the mesovarium proximad to these testis lobes, but only at the anterior end of the testis band. The posterior end of the mesovarium in adult females with normal eggs may contain a few small eggs or brown bodies, but are usually without any reproductive elements.

Sections were made of portions of the bands of testis lobes found in three of the young animals, viz., #18, #7. Figure 75, a transverse section of the band in Myxine #18, shows the minute structure of one of these testis bands. The structure is similar to that of the young European Myxine as described by Nansen (87), Cunningham ('87 and '92), and Schreiner ('05). The testis band consists of a large mass of stroma cells and many primitive germ cells which lie among the stroma cells. The band is attached to the digestive tract by the continuation of the mesovarium, though here it may perhaps be called more properly the mesorchium. Here and there in a transverse section of the band is a small follicle formed by a single layer of stroma cells, inside of which are from four to two or three dozen spermatogonia. No mitotic figures are present in any of the spermatogonia. On the contrary, the cells are in a resting stage, the nucleolus being visible in most of them. The entire mass is sur-

rounded by the squamous epithelium of the mesorchium.

Myxine #7 is older than #18, and its testis lobes are more advanced in development, as is shown by figure 76. The follicles are more numerous, are larger, and contain more spermatogonia. The stroma cells are much less numerous. No mitotic figures are present, but the chromatin of many of the spermatogonia is scattered throughout the cell and the nucleolus has disappeared. The epithelium which surrounds the testicular mass is thicker, and here and there it turns inward, thus cutting the testis band into lobes. Small eggs occur along the entire distal margin of the mesorchium anterior to the testis band. The follicles of neither #18 nor #7 contain any spermatozoa. These specimens are not sufficiently advanced in development to indicate whether they will eventually be male or female.

Male

Myxine #15, an animal 62 centimeters long, has a testis band 5 mm. wide along the distal margin of the posterior 9½ centimeters of the mesorchium. Anterior to this band the mesorchium is of comparatively uniform width (about 7 mm.) all the way to the anterior end, and contains along its distal margin numerous brown bodies (degenerated eggs) but no normal eggs. No brown bodies, however, are present in the portion of the mesorchium which is occupied by the testis band. The mesorchium is not folded, but is straight and flat (fig. 82). There are no indications that this animal ever produced large eggs, and it is considered as an almost mature male. Only about one-half of the follicles contain cells which show mitotic figures, but no spermatozoa were found. A transverse section of the testis band (fig. 77) shows that in this specimen the large follicles are larger than the largest ones in specimens #18 and #7, but they range in size

from small to large and are closely crowded together, so that the stroma cells are limited to narrow strips between the follicles or between the latter and the mesorchial sheath. Almost every stage of mitosis is represented. Not all the cells of an individual follicle show mitotic figures, but what figures are present are approximately in the same stage (fig. 78).

A striking difference between the testis band of Myxine #15 a and those of specimens #18 and #7 is the fact that the single layer of squamous mesorchial epithelium which envelopes the entire band has been here and there converted into a columnar epithelium. The long, spindle-shaped cells of the mesorchial sheath become shortened and arranged in palisade order. These columnar cells have not entirely surrounded the testis band, but in places the squamous epithelium is still present and forms the sheath of the band.

In two other specimens, #12 and #13, this process of conversion of the mesorchial sheath into columnar epithelium has advanced until the entire testis band is enveloped by it. The band in these two animals is very different from that of any other specimen. In the first place, the band extends the entire length of the mesorchium (fig. 83). Specimen #12 has the general appearance of being older than #13. At the anterior end of the genital fold the width of the mesorchium and the testis band together is 4 mm., and it increases at once to 5 mm., then fluctuates between 4 and 5 mm. to a point about 7 centimeters from the extreme posterior end. At this point the combined width of the band and the mesorchium increases to 7 mm. and remains this to the posterior end of the mesorchium. The testis band is suspended from the distal end of the mesorchium, and at the anterior end it is 1 mm. wide x 1/2 mm. thick. The band increases grad-

ually in both width and thickness as it proceeds posteriorly, and at mid-region it is 2 mm. wide x 3/4 mm. thick. At a point 7 centimeters from the posterior end it reaches its maximum size, 6 mm. wide x 1 mm. thick, and retains these dimensions to the extreme posterior end, immediately in front of the genital pore. The testis band of specimen #13 is neither as wide nor as thick as that of #12, the widest part being 5 mm. Also, it is not as lobulated as the band of #12, and it is yellowish in color instead of reddish as in #12. In the latter the small lobules give a granular appearance to the band, which is especially pronounced in the posterior region. There is not the slightest trace of eggs, normal or degenerated, at any place in the mesorchium of either #12 or #13. Myxine #12 is 67 centimeters long and the testis band is 36 centimeters. Specimen #13 is 63 centimeters long and its testis band measures 35 centimeters.

Transverse sections cut in all parts of the testis bands of these two animals reveal the fact that the bands are of uniform and peculiar structure. They do not resemble the testis bands of younger Myxine nor those of Bdellostoma, as figures 80 and 81 show. The squamous mesorchial epithelium has been completely converted into the palisade layer of columnar cells. In transverse section the band is cone-shaped, and deep notches in the sides cut it into irregular lobes, leaving a central core of stroma. The latter has been entirely converted into fibrous connective tissue which contains many blood capillaries. Nowhere in the bands is there the slightest trace of primitive germ cells or follicles. Figure 81, a transverse section from the posterior end of the band of Myxine #12, shows another peculiar condition. At the base of the band, in a pocket formed between the lobes, there is a tangled skein of columnar epi-

thelium which is of the same width as the columnar epithelium around the band. Here and there this skein is continuous with the epithelium which envelopes the band. It extends through all the sections cut in the posterior region of the testis band of Myxine #12, but occurs nowhere else. The writer has been unable to explain what this tissue may be.

Myxine #12 and #13 are old animals, as is indicated by their general condition, viz., the thick, hard skin, the reddish, coarse fibers of the muscular tissue, the enlarged, coarse, dark-brown liver, the great diameter of the body, etc., etc. The peculiar condition of their testis bands is interpreted as due to their having become completely sterile with old age. Myxine #18 and #7, young, immature males, have many primitive germ cells, a few follicles and very little connective tissue in the testis band. Myxine #15, and adult male, has few germ cells, many follicles, and much connective tissue around and between the follicles in the testis lobes. In places the squamous epithelial covering of the band has been converted into a columnar epithelium, but sufficient squamous epithelium remains to permit easy rupture of the follicles when they are ripe. The band is notched only slightly here and there. In specimens #12 and #13 the germ cells and follicles have entirely disappeared, and the bands are completely filled with fibrous connective tissue and blood capillaries, and all the squamous mesorchial sheath has been converted into a columnar epithelium. The testis bands are deeply notched in all parts so that they are cut up into lobes. The testis bands in these two animals have lost their power of functioning and are completely sterile.

Bdellostoma

Female

The generative organs of Bdellostoma closely resemble those of Myxine in many respects. The ovary is single, occurring on the right side only, and is suspended in the body cavity from a mesovarium which extends from the region of the gall bladder to the posterior end of the body cavity, a distance which is approximately one-half the entire length of the body. Unlike Myxine, however, the proximal margin of the mesovarium is always attached to the mesentery about one-third the width of the latter from the alimentary canal. The mesentery and mesovarium are more delicate than in Myxine.

In the females which have eggs 2 mm. long or longer, the mesovarium is approximately 10 to 15 mm. wide. Where the large eggs are attached the mesovarium is stretched into strands which are 25 to 30 mm. long, and between the eggs it is 10 to 20 mm. wide.

The distribution of the eggs is very similar to that in Myxine. There are all gradations of sizes of young eggs from mere dots to those 2 mm. long in adult females, but there are no intermediate sizes between the latter and any larger eggs or corpora lutea that may be present.

The following table will give some conception in regard to the number of large eggs which may occur in an adult female:

Number of specimen	Size of Eggs	Number of eggs
#25	1-1½ x 3-6	77
#17	2½-3 x 10-11	20
#1	3-3¼ x 12-13	28
#23	3-3½ x 13-14	10
#24	3-3½ x 14-15	10
#4	3-3½ x 14-15	23
#15	5½-6 x 20-21	31

Two of the specimens of Bdellostoma contain corpora lutea, one having eleven, the other twenty-four, and all show signs of degenera-

tion. Small brown ovals, representing degenerated eggs, are scattered irregularly among the eggs.

In all the females the eggs extend to within one or two centimeters of the posterior end of the mesovarium (fig. 84), and there are sometimes a few very small eggs in this most posterior part. No testis lobes are present in any part of the mesovarium of any of the females, not even in the posterior region.

Male

No female elements occur in any of the males, and none of the mesorchia present the appearance of ever having contained eggs. The general structure and appearance of the mesorchium is very similar in all the specimens. It extends from the region of the gall bladder to the caudal end of the body cavity, and is attached to the mesentery along a line which is about one-third the width of the latter from the alimentary canal (fig. 85). At the anterior end the mesorchium is merely a line along the dorsal surface of the digestive tract. At a point opposite the posterior end of the gall-bladder it leaves the alimentary canal and gradually ascends in the mesentery to its definitive position. Immediately behind the gall-bladder it is from 1 to 3 mm. wide, and retains this width to the testis lobes at the posterior end, usually decreasing slightly in width just before reaching the lobes. In most of the males the mesorchium, which is very delicate, contains no genital elements in the anterior and mid-regions, but in some individuals very small testis lobes are scattered along the distal margin of the mesorchium from the extreme anterior end to the band of lobes at the posterior end. One male has a single lobe about ½ mm. in diameter at the anterior end of the mesorchium and no others excepting those in the testis band at the posterior end.

Other specimens have two or three such small lobes, still others a dozen or more, while one animal has so many that they look as though at one time they formed a continuous narrow band along the distal margin of the mesorchium.

The large mass of testis lobes is confined to the posterior end of the mesorchium, and consists of a great many lobules closely crowded together into a band. This band varies in length, in the seven males examined, from 3 to 8 centimeters and in width from 2 to 7 millimeters. There is no correlation between the length of the testis band and the length of the animal, as is shown by the following table:

		Testis Band	
Specimen	Length	Width	Length
#6	33 cm.	2 mm.	$5\frac{1}{2}$ cm.
#16	36 "	2 "	5 "
#21	$36\frac{1}{2}$ "	2 "	6 "
#10	$36\frac{1}{2}$ "	5 "	$3\frac{1}{2}$ "
#1	$38\frac{1}{2}$ "	5 "	$4\frac{1}{2}$ "
#2	$40\frac{1}{2}$ "	7 "	$6\frac{1}{2}$ "
#8	42 "	5 "	$7\frac{1}{2}$ "

In the longer, i.e., the older, animals the testis band is wider and thicker than in the younger males.

The testis bands are folded more or less in the young males and considerably in the older animals. In all, the bands have a very granular appearance (fig. 85). The bands in the younger males are light gray in color, and yellowish in older animals.

Transverse sections of the testis bands show that in minute structure they are very similar to those of Myxine. Single germ cells and follicles of all sizes from very small to large are present. In a single section all stages of mitotic figures may occur, and many of the follicles contain spermatozoa (fig. 79). Each follicle has for its wall a single row of stroma cells, arranged end to end, and

outside this are two or more concentric layers of fibrous connective tissue. Capillaries occur here and there in the connective tissue and stroma between the follicles. The primitive germ cells are limited to the distal end of the band, and here the follicles are smaller, their walls are not so prominent and there is less connective tissue than in the proximal part where the large follicles are located. The entire band is covered by a single layer of squamous epithelium which is a continuation of the mesorchium. In no place is there columnar epithelium around the testis band as is described for Myxine.

Cunningham ('87) and Nansen ('87) have advanced the theory that Myxine is a protandric hermaphrodite, functioning as a male when young (28--32 cm. long) and as a female when older (32--35 cm.). Nansen thinks the change in sex occurs when the animal reaches a body length of about 32 or 33 cm. Out of hundreds of specimens examined by each of these investigators, only a few males were found (Cunningham 8, Nansen 'very few') and most of these were immature. Nansen regards the males as merely transformed hermaphrodites and found all transition stages between males and common hermaphrodites. Cunningham found that in "nearly all specimens with very immature eggs the posterior portion of the sexual organ had the same structure as the testis", and that "in all specimens with well-developed ovarian eggs ********** with one exception, no testicular portion was present in the sexual organs", there he concluded "that in the young state the females are nearly, but not quite always hermaphrodite, and that the testicular portion normally disappears as the eggs become more mature". Nansen states that "on opening large specimens of Myxine, we generally find well developed ova in their sexual organs. If we, however, take smaller specimens, of about 28--32 cm. in length, and examine

their sexual organs, we generally find that the anterior portion is but slightly prominent, and contains very small and young ova, whilst the posterior portion is often very broad and prominent, is lobate, and has a distinct whitish colour along its margin, and has, in all respects, the appearance that we would expect to find in a testis; and that it really is." He concludes that "Myxine is generally, or always (?), in its young state, a male; whilst at a more advanced age it becomes transformed into a female. Indeed, I have not yet found a single female that did not show traces of the early male stage."

Schreiner found only 19 pure males out of 2500 specimens examined, and they were seldom over 33 cm. long, the majority of them being 30--31 cm. In a quite preponderating number of individuals which were longer than 33 cm. there was a more or less well-developed ovary and the testis part was sterile, and in the males there was a more or less well-developed testis and an abnormal or rudimentary ovary. In the females the ovary was well-developed and the testis part was usually rudimentary or occasionally completely sterile. The testis was always abnormal in both young and old females. In addition to functional males and females, Schreiner found individuals in which both testis and ovary were degenerated, and these he classed as sterile animals. He also found normal females 22 cm. long and less, and states that, "lässt sich das häufige Vorkommen von jungen Weibchen unmöglich mit der Annahme eines protandrischen Hermaphroditismus bei diesem Tiere vereinigen." Schreiner believes that Myxine is dioecious.

It is well known that Bdellostoma is an animal of separate sexes. The fifteen adult females examined by the writer have no

trace of testis lobes in any part of the mesovarium, and no female elements occur in the mesorchium of any of the eight adult males. The females range in length of body from 34 to 40 cm., and the males from 36 to 42 cm. That is to say, in this particular lot of animals some of the functional males are larger than the adult females, hence it is certain that Bdellostoma is not a protandric hermaphrodite. It is improbable, to say the least, that of two animals so closely related as Bdellostoma and Myxine, the one should have normal, separate sexes while the other should possess such a peculiar method of reproduction as protandric hermaphroditism.

Furthermore, as Dean ('99) has suggested, the occurrence of large males would also discredit the theory that Myxine is a protandric hermaphrodite. Myxine #15, described above, is undoubtedly a normal male in which the only female sexual products are small, completely degenerated eggs, and specimens #12 and #13 are males which have become sterile with age and which have no female elements whatever. Myxine #15 is 62 cm. long, #12 is 67 cm., and #13 is 63 cm. The average length of the females with large eggs, from 18 to 25 mm. long, is 59 centimeters, the longest being 64 centimeters. Here, then, we have one normal and two sterile males which are longer than the average female with large eggs. In view of these facts, it seems impossible that Myxine can be a protandric hermaphrodite.

III. SUMMARY

1. A central duct is present in the pronephros of both Bdellostoma and the North-American Myxine, but it is in a state of degeneration in both animals. This degeneration is more advanced in Myxine than in Bdellostoma, so that it includes the inner ends of the

pronephric tubules and all parts of some of the largest tubules.

2. The 'central mass' which lies in the pronephric vein is not a series of glomeruli, but represents the disintegrated central duct (including the inner ends of tubules in Myxine).

3. The Malpighian body of the pronephros in both Bdellostoma and Myxine is located at the posterior end of the pronephros, and in appearance and structure closely resembles the Malpighian bodies of the mesonephros. It is formed by the fusion of two or more glomeruli.

4. The glomerulus of the pronephros in young Myxinoids is exposed to the pericardial cavity through a large opening, thus resembling a glomus. This opening becomes constricted to a small tubule in adult animals.

5. The large vein which extends along the base of each pronephros communicates with the lumen of the central duct through large natural openings. The pronephric tubules connect the lumen of the duct with the pericardial cavity, and the latter opens into the peritoneal cavity through the large pericardo-peritoneal foramen, while the body cavity opens into the cloaca through the genital pore. Thus the vascular system is in communication with the exterior of the body.

6. The morphology of the pronephros does not reveal any positive indications as to its function. The granular coagulum in the tubules and duct suggests excretion. This question can probably be determined only by physiological methods.

7. The tubules of the pronephroi of adult Bdellostoma are approximately the same diameter, while those of Myxine vary in size.

8. Each lobule in the pronephros does not represent an original pronephric tubule.

9. The mesonephric ducts of Myxinoids probably possess a secretory as well as an excretory function, as is suggested by the long epithelial cells, the increased surface of these by ridges, the large granules at the distal ends of the cells, and the yellowish bodies in the cells. Also, isolated pieces of the duct contain waste particles like those present in all parts of the continuous portion of the duct.

10. The mesonephric ducts of adult male Bdellostomae are larger than those of adult females, and the epithelial ridges within them are larger.

11. The mesonephric ducts of Myxinoids open separately into the cloaca.

12. The tubules of the mesonephric Malpighian bodies in Bdellostoma are structurally of two types.

13. When some eggs in the ovary of Myxinoids attain a size exceeding about 2 mm. in length, all the smaller eggs are arrested in growth until the large eggs reach maturity and have been ejected from the body.

14. Many of the small, young eggs in Myxinoids degenerate, forming the 'brown bodies'.

15. When a mature egg is ejected from the ovary it leaves attached to the mesovarium a 'corpora luteum', which is composed of the outer envelope of mesovarium which surrounded the egg. The corpora lutea degenerate.

16. After the testis of old males ceases to function, the peritoneal epithelium which covers the testicular band becomes changed from squamous to columnar; the empty testicular follicles completely disappear, and the band becomes converted into a mass of

connective tissue penetrated by blood vessels.

17. Neither Bdellostoma nor Myxine is a protandric hermaphrodite.

18. The urogenital system of the North-American Myxine does not present any specific differences from that of the European animal. On the other hand the great difference in size of mature individuals from the two sides of the Atlantic would appear to support the distinctness of M. limosa of Girard from the M. glutinosa of Linneaus.

BIBLIOGRAPHY

Ayers, Howard
'94. Bdellostoma dombeyi, Lac. Biological lectures at Woods Hole in summer session of 1893. Ginn & Co.

Beard, J.
'92. Notes on Lampreys and Hags. Anat. Anz., 8; 59-60. Also, Brit. Assoc. Rep., Edinburgh, '92, p. 790.

Burne, R. H.
'98. The "Porus genitalis" in the Myxinidae. Journ. Linn. Soc. London, 26; 487-495.

Cole, F. J.
'05. Notes on Myxine. Anat. Anz., 27; 323-326.

'14. Notes on the vascular system of Myxine. Anat. Anz., 46; 478-485.

Collinge, Walter E., and Swale, Vincent.
'96. On the so-called suprarenal bodies in Cyclostoma. Anat. Anz., 12; 232-241.

Cunningham, J. T.
'86. The reproductive organs of Bdellostoma. Trans. Roy. Soc. Edinburgh, 33; 247-250. Abstr. in Journ. R. Micr. Soc. London, 1888, p. 192-193.

'87a. On the structure and development of the reproductive elements in Myxine glutinosa, L. Quart. Journ. Micr. Sci., 27; 49-76.

'87b. Herr Max Weber and the genital organs of Myxine. Zool. Anz., 10; 241-244.

'87c. The reproduction of Myxine. Zool. Anz., no. 256; 390-392.

'92. Spermatogenesis in Myxine glutinosa. Quar. Journ. Micr. Sci., 33; 169-186.

Dean, Bashford
'97. The Columbia University zoological expedition of 1896. Trans. N.Y. Acad. Sci., 16; 33-42.
'97. On the development of the Californian hag-fish, Bdellostoma stouti, Lock. Quar. Journ. Micr. Sci., N.S. 40; 269-279.

'99. On the embryology of Bdellostoma stouti. A general account of Myxinoid development from the egg and segmentation to hatching. Festschr. Kupffer, p. 221-276.

'00. The egg of the hag-fish, Myxine glutinosa, Linn. Mem. N. Y. Acad. Sci., 2; 33-45.

'03. The eggs of the eastern Atlantic hag-fish, Myxine limosa, Gir. Science, N. S., 17, 428; p. 433.

Felix, W.
'97. Die Price'sche Arbeit, "Development of the excretory organs of a Myxinoid (Bdellostoma stouti Lockington)", und ihre bedeutung für die Lehre von der Entwickelung des Harnssystems. Anat. Anz., 13; 570-599.

Girard, Chas.
'58. Icthyological notices. Proc. Phila. Acad., 223.

Jackson, C. M.
'01. An investigation of the vascular system of Bdellostoma dombeyi. Journ. Cin. Soc. Nat. Hist., 20; 13-47.

Kirkaldy, J. W.
'94. On the head kidney of Myxine. Quart. Journ. Micr. Sci., 35; 353-359.

Lewis, F. T.
'04. The question of sinusoids. Anat. Anz., 25; 261-279.

Maas, Otto.
'97. Ueber Entwicklungsstadien der Vorniere und Urniere bei Myxine. Zool. Jahrb., Abt. Anat., 10; 473-510.

Minot, C. S.
'98. On the veins of the Wolffian Bodies in the pig. Proc. Boston Soc. Nat. Hist., 28; 265-274.

'00. On a hitherto unrecognized form of blood circulation without capillaries in the organs of Vertebrata. Proc. Boston Soc. Nat. Hist., 29; 185-215.

Müller, J.
'43. Untersuchungen über die Eingeweide der Fische, Schluss der vergleichenden Anatomie der Myxinoiden. Abhandl. der könig. Akad. der Wissens. zu Berlin, 109-170.

Müller, W.
'75. Ueber das urinogenitalsystem des Amphioxus und der Cyclostomen. Jena. Zeit. f. Naturwiss., 9; 94-129.

Nansen, Fridtjof
'87. A protandric hermaphrodite (Myxine glutinosa, L.) amongst the vertebrates. Bergen's Mus. Aarsber., p. 1-34.

Price, G. C.
'96. Some points in the development of a Myxinoid (Bdellostoma stouti Lockington). Verh. Anat. Ges., 10; 81-86. Zur Ontogenie eines Myxinoiden (Bdellostoma stouti, L.). Sitz. Ber math-phys. Clkbayer. Akad. Wiss.

München., 26; 69-74.

'97. Development of the excretory organs of a Myxinoid, Bdellostoma stouti Lockington. Zool. Jahrb., Abth. Anat. Ontog., 10; 205-226. Bastr. Journ. R. Micr. Soc. London, 5; 316.

'04. A further study of the development of the excretory organs in Bdellostoma stouti. Amer. Journ. Anat., 4; 117-138.

'10. The structure and function of the adult head-kidney of Bdellostoma stouti. Journ. Exper. Zool., 9; 849-864.

Prince, E. E.
'15. The curious egg of the hagfish. Ottawa Naturalist, 29; p. 14.

Putnam, F. W.
'73. Notes on the genus Myxine and genus Bdellostoma. Proc. Boston Soc. Nat. Hist., 16; 127-135, 156-160.

Schreiner, A. und K. E.
'05. Ueber die Entwicklung der männlichen Geschlechtszellen von Myxine glutinosa. Arch. Biol., 21; 183-314, 315-355.

'08. Zur Spermienbildung der Myxinoiden. (Ueber die Entwicklung der männlichen Geschlechtszellen von Myxine glutinosa L.). Arch. Zellforschung, 1; 152-231.

Schreiner, K. E.
'04. Ueber das Generationsorgan von Myxine glutinosa. Biol. Centralbl., 24; 91-104, 121-129, 162-173.

Semon, Rich.
'96. Das Excretionssystem der Myxinoiden in seiner Bedeutung für die morphologische Auffassung des Urogenitalsystems der Wirbelthiere. Festschr. C. Gegenbauer, 3; 167-192.

'97a. Das Excretionssystem der Myxinoiden. Anat. Anz., 13; 127-137.

'97b. Vorniere und Urniere. Anat. Anz., Bd. 13, 260-264.

Semper, C.
'75. Das Urogenitalsystem der Plagiostomen und seine Bedeutung für das der übrigen Wirbelthiere. Arbeiten aus dem Zoologisch. Institut zu Würzburg, 2; 167-509.

Spengel, J. W.
'97a. Die Excretionsorgane von Myxine. Anat. Anz., 13; 49-60.

'97b. Semon's Schilderung des Mesonephros von Myxine. Anat. Anz., 13; 211-216.

Weber, Max.
'87. Erwiderung an Herrn Cunningham. Zool. Anz., 253; 218-321.

Weldon, W. F. R.
'84. On the headkidney of Bdellostoma, with a suggestion as to the origin of the suprarenal bodies. Quart. Journ. Micr. Sci., 24; 171-182.

Worthington, Julia.
'05. Contribution to our knowledge of the Myxinoids. Amer. Natural., 39; 625-663.

EXPLANATION OF PLATES

Abbreviations

a	dorsal aorta
ac	anterior cardinal vein
al	alimentary canal
an	anus
au	auricle
b	Bowman's capsule
bc	base of compound tubule
bm	basal membrane
bs	blood sinus
c	connective tissue
cb	band of connective tissue
cd	central duct
ce	columnar epithelium
cl	corpora lutea
clo	cloaca
cm	central mass
co	blood corpuscle
cp	common portal vein
d	distal margin of mesovarium or mesorchium
dc	ductus Cuvieri
dm	degenerated Malpighian body
do	degenerated ova, 'brown bodies'
e	connective tissue envelope
eb	epithelium of base of compound tubule of mesonephros
el	epithelium of plain mesonephric tubule
em	epithelium of mesonephric duct
en	epithelium of neck of compound mesonephric tubule
eo	endothelium
ep	epithelium
f	funnel-shaped mouth of pronephric tubule
fl	testicular follicle
g	glomerulus
gb	gall bladder
gc	giant blood corpuscle
gp	process composed of granules
i	intertubular space
liv	liver
lp	left postcardinal vein
m	Malpighian body of mesonephros
md	mesonephric duct
mi	mesoderm of peritoneum
mn	mesonephros
mp	Malpighian body of pronephros
mr	mesorchium
ms	mesovarium
mt	tubule of Malpighian body
n	nucleus
nc	neck of compound mesonephric tubule
nu	nuclear mass
o	ovary
op	opening of central duct into pronephric vein
ov	ova

p	plain mesonephric tubule
pc	pericardium
pcc	pericardial cavity
pf	pericardo-peritoneal foramen
pg	primitive germ cell
ph	portal heart
pn	pronephros
pnr	pronephros
pt	epithelium of peritoneum
pv	pronephric vein
ra	renal artery
rac	right anterior cardinal vein
rp	right postcardinal vein
rpv	right pronephric vein
s	stroma cells
sa	somatic artery
sc	skein of columnar epithelium
se	squamous epithelium
si	supra-intestinal vein
so	somite
ss	sheath of stroma cells around testicular follicle
st	septum transversum
t	pronephric tubule
tb	testis band
tu	mesonephric tubule
v	blood vessel
w	waste granules
y	yellowish granules
z	pericardial attachment to dorsal aorta and alimentary canal

PLATE I

Fig. 1. Right pronephros of Bdellostoma #6, showing its position in the pericardial cavity. Natural size.

Fig. 2. Left pronephros of Bdellostoma #6, showing position in the pericardial cavity. Natural size.

Fig. 3. Right pronephros of Myxine #5, showing position in the pericardial cavity. Natural size.

Fig. 4. Left pronephros of Myxine #5, showing position in the pericardial cavity. x1½.

Fig. 5. Transverse section through the right pronephros of Bdellostoma #6. Camera, x25.

Fig. 7. Left pronephros of Bdellostoma #16. x4.

Fig. 8. Left pronephros of Bdellostoma #18. x4.

Fig. 9. Left pronephros of Bdellostoma #7. x4.

Fig. 10. Right pronephros of Bdellostoma #16. x4.

Fig. 11. Right pronephros of Bdellostoma #18. x4.

PLATE II

Fig. 11a. Transverse section of the right pronephros of Bdellostoma #10, illustrating the three-sided shape.

Fig. 12. Millimeter paper reconstruction of the right pronephros of Bdellostoma #15. x25.

Fig. 13. Pronephric tubule with fullel-shaped mouth.

Fig. 14. Pronephric tubules in longitudinal and transverse section. Bdellostoma #15.

Fig. 15. Transverse section through two pronephric tubules showing relation of the vascular endothelium to the tubules when a blood sinus occupies the space between the tubules. Bdellostoma #15.

PLATE III

Fig. 16. Enlarged drawing of columnar epithelial cells of a pronephric tubule. Bdellostoma #15.

Fig. 17. Transverse section through pronephros of Bdellostoma #10, showing the endothelium of the pronephric vein continuing around the central mass.

Fig. 18. Transverse section through the central mass. Bdellostoma #15.

Fig. 19. Enlarged drawing of the central mass. Bdellostoma #15.

Fig. 20. Transverse section through pronephros of Bdellostoma #15, showing communication between the central duct and the pronephric vein, with nuclear mass in the opening; also shows pronephric vein opeening into the space between the tubules, thus making a blood sinus. Not all the pronephric tubules are included in the drawing.

Fig. 21. Transverse section in another part of pronephros of Bdellostoma #15 which also shows the central duct communicating with the pronephric vein and the opening filled with the nuclear mass. Not all of the tubules are shown.

Fig. 22. Transverse section through pronephros of Bdellostoma #6, showing the central duct in communication with the pronephric vein through a large opening which is filled with a nuclear mass.

Fig. 23. Transverse section through a pronephric tubule of Myxine #10, showing connective tissue surrounding the epithelium.

PLATE IV

Fig. 24. Transverse section through a pronephric tubule of Myxine #11, showing connective tissue.

Fig. 25. Section through some tubules of pronephros of Myxine #15, showing the large amount of connective tissue around the tubules.

Fig. 26. Transverse section through a pronephric tubule of Myxine #10, showing blood sinus around the tubule.

Fig. 27. Transverse section through some tubules of pronephros of Myxine #10, showing difference in size of the tubules.

Fig. 28. Transverse section through pronephros of Myxine #11, showing the central duct in the centralmass.

Fig. 29. Transverse section through pronephros of Myxine #11, showing central duct in communication with the pronephric vein. Camera lucida, x50.

PLATE V

Fig. 30. Longitudinal section through the central duct in pronephros of Myxine #11. Camera lucida, x50.

Fig. 31. Longitudinal section through the central duct of one of the youngest specimens, Myxine #18. Camera, x90.

Fig. 32. Transverse section through pronephros of Myxine #10, showing the central duct. Not all the tubules are included in the sketch. Camera lucida, x30.

Fig. 33. Transverse section through pronephros of Myxine #11, showing the central duct with its columnar walls intact. Camera lucida, x50.

Fig. 34. Transverse section through pronephros of one of the youngest specimens, Myxine #18, showing the central mass. Camera lucida, x50.

Fig. 35. Longitudinal section through the central mass in pronephros of Myxine #11. Camera lucida, x90.

PLATE VI

Fig. 36. Section through pronephros of Myxine #15 which shows a broad band of connective tissue extending from the base of the tubules into the pronephric vein. Camera, x50.

Fig. 37. Transverse section through a degenerated Malpighian body immediately posterior to the left pronephros of Myxine #15. Camera lucida, x90.

Fig. 38. Transverse section through a degenerated Malpighian body immediately posterior to the left pronephros of Myxine #11, with a blind tubule beside it. Camera, x90.

Fig. 39. Transverse section through pronephros of Bdellostoma #15, showing Bowman's capsule of the Malpighian body opening into the pericardial cavity. Camera lucida, x50.

Fig. 40. Transverse section through the Malpighian body of the left pronephros of Bdellostoma #16, showing lobulated structure of the glomerulus and the opening of Bowman's capsule into the pericardial cavity. Camera, x90.

PLATE VII

Fig. 41. Section through the Malpighian body of one of the oldest specimens (Myxine #10), showing degeneration of the glomerulus. Camera lucida, x19.

Fig. 42. Section through the Malpighian body of pronephros of a young Myxine (#18), showing double glomerulus. Camera lucida, x50.

Fig. 43. Section through Malpighian body of pronephros of a young Myxine (#18), showing the glomerulus exposed to the pericardial cavity through a large opening and resembling a glomus. Camera lucida, x50.

Fig. 44. Transverse section through mesonephros of Bdellostoma #17, cut in mid-region of body cavity, showing relation of the ducts to blood vessels and peritoneum.

Fig. 45. Dorsal view of the excretory system of Bdellostoma #16. ½Natural size. Male.

Fig. 46. Dorsal view of the excretory system of Bdellostoma #15. ½Natural size. Female.

Fig. 47. Dorsal view of posterior ends of mesonephric ducts of Bdellostoma #16. Natural size.

Fig. 48. Side view of posterior end of left mesonephric duct of Bdellostoma #16. Natural size.

PLATE VIII

Fig. 49. Ventral view of excretory system of a young male, Bdellostoma #6. ½ natural size.

Fig. 50. Transverse section through the mesonephric duct of an adult male, Bdellostoma #16, cut in the mid-region of the body cavity. Camera lucida, x19.

Fig. 51. Transverse section through the mesonephric duct of an adult female, Bdellostoma #15, cut in the mid-region of the body cavity. Camera lucida, x19.

Fig. 52. Transverse section through the anterior end of a mesonephric duct of Bdellostoma #6, x90.

Fig. 53. Enlarged sketch of a ridge in the epithelial lining of a mesonephric duct. Bdellostoma.

Fig. 54. Enlarged sketch of the anterior ends of the mesonephric ducts of Bdellostoma #4, mounted in damar.

Fig. 55. Enlarged ventral view of the mesonephric ducts of Bdellostoma #8, showing location of the Malpighian bodies with reference to the somites.

Fig. 56. Enlarged sketch of mesonephric ducts of Bdellostoma #16 showing the distribution of the arteries to the Malpighian bodies.

Fig. 57. Longitudinal section through the tubule of a Malpighian body of the mesonephros, Bdellostoma #17. 'Plain' type of tubule. Camera lucida, x90.

PLATE IX

Fig. 58. Reconstruction of a 'plain' mesonephric tubule of Bdellostoma; diagrammatic.

Fig. 59. Diagrammatic reconstruction of a 'compound' mesonephric tubule of Bdellostoma.

Fig. 60. Sketch showing transition between the cells of the neck and those of the base in a 'compound' tubule. x250.

Fig. 61. Transverse section of a 'compound' tubule showing opening of the base into the mesonephric duct. Camera, x50.

Fig. 62. Transverse section through mesonephric duct of Bdellostoma #15, showing a Malpighian body and its tubule. Camera lucida, x30.

Fig. 63. Transverse section through mesonephric duct of Myxine #12. Camera lucida, x50.

Fig. 64. Enlarged sketch of epithelial ridges in mesonephric duct of Myxine #12, showing core of yellowish granules.

Fig. 65. Sketch of ovary of one of the youngest specimens of Myxine (#18). Natural size.

PLATE X

Fig. 66. Enlarged portion of ovary of an adult Myxine (#16), showing distribution of eggs. x2.

Fig. 67. Sketch of large egg in Myxine #2. Natural size.

Fig. 68. Portion of mesovarium containing 'corpora lutea'. Myx-

ine #20. Natural size.

Fig. 69. A large corpus luteum from Myxine #2. Natural size.

Fig. 70. Small corporea lutea from Myxine #5. Natural size.

Figs. 71, 72, and 73. Sections of 'brown bodies' from Myxine showing three stages in the degeneration of eggs. Camera lucida, x30.

Fig. 74. Section through small eggs from Myxine #8. Camera lucida, x30.

PLATE XI

Fig. 75. Transverse section through the testis band at the posterior end of the mesovarium of a young Myxine (#18). Camera lucida, x50.

Fig. 76. Transverse section through the testis band at the posterior end of the mesovarium of an older, but immature Myxine (#7). Camera lucida, x30.

Fig. 77. Transverse section through the testis band of Myxine #15, a normal male. Camera lucida, x50.

Fig. 78. Enlarged sketch of a transverse section through a follicle in the testis of Myxine showing the spermatogonia in the asteroid stage.

Fig. 79. Transverse section through a follicle in the testis band of Bdellostoma #7, showing spermatozoa.

Fig. 80. Transverse section through the anterior region of the testis band of Myxine #12. Camera lucida, x30.

Fig. 81. Sketch of a portion of transverse section through the posterior region of the testis band in Myxine #12. Camera lucida, x30.

PLATE XII

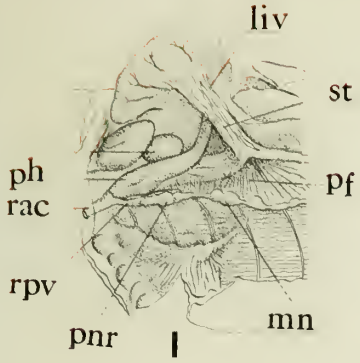
Fig. 82. Sketch of the posterior end of the genital band in Myxine #15. Natural size.

Fig. 83. Sketch of the testis band in Myxine #12. $\frac{1}{4}$ natural size.

Fig. 84. Sketch showing extreme posterior end of the genital band in a female Bdellostoma (#9). Natural size.

Fig. 85. Sketch of a male Bdellostoma (#8) with body cavity open, showing the testis band. $\frac{1}{2}$ natural size.

PLATE I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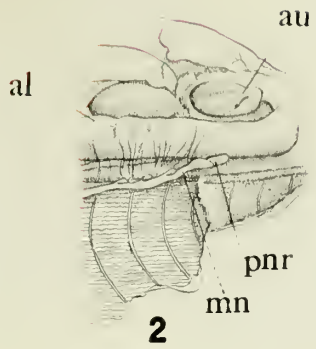
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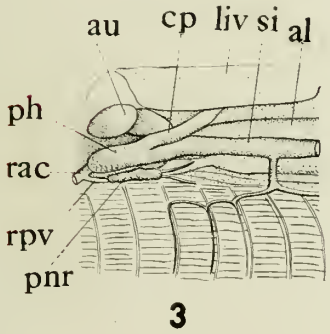
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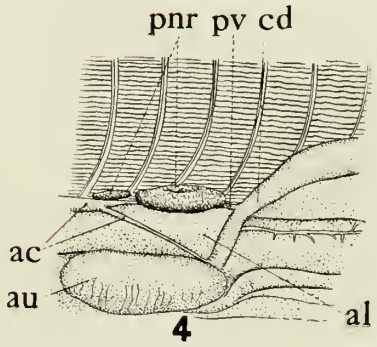
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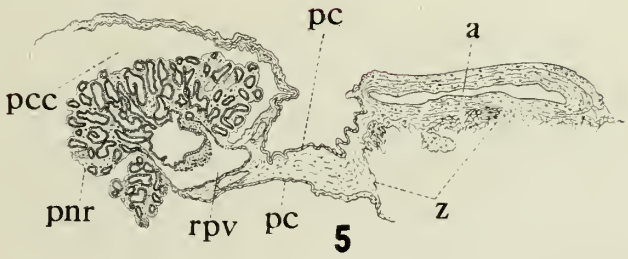
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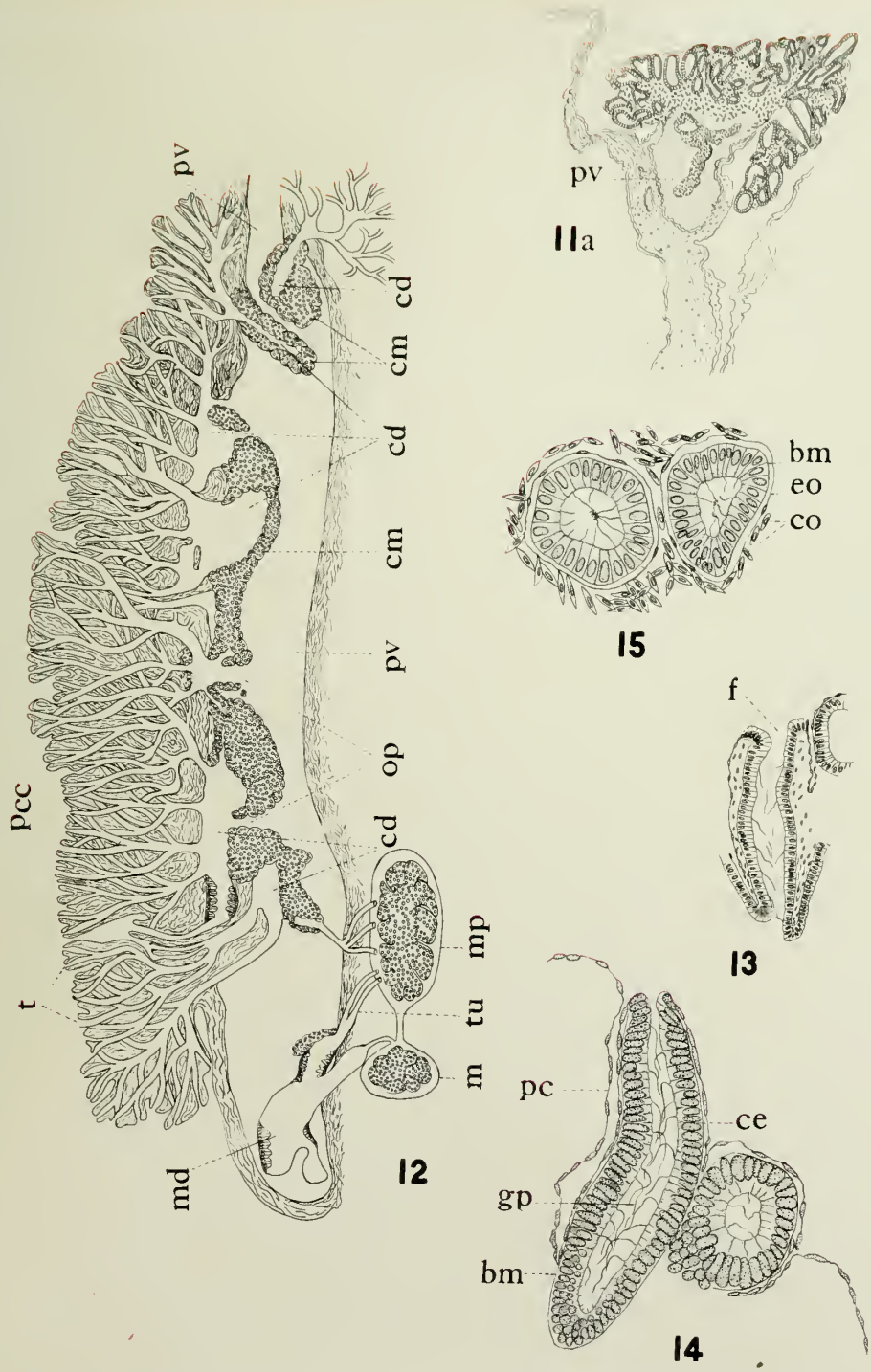
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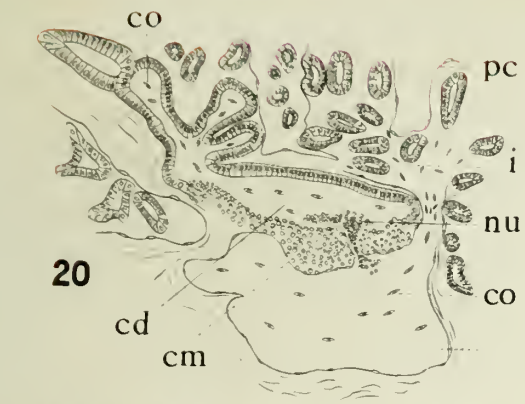
PLATE III



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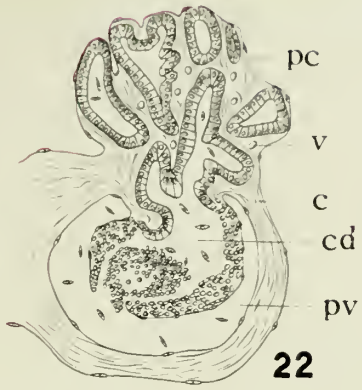

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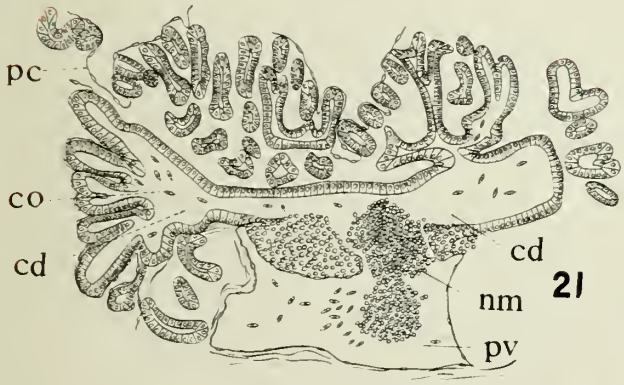

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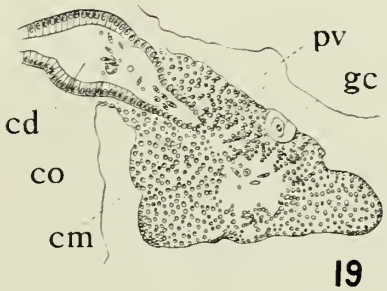

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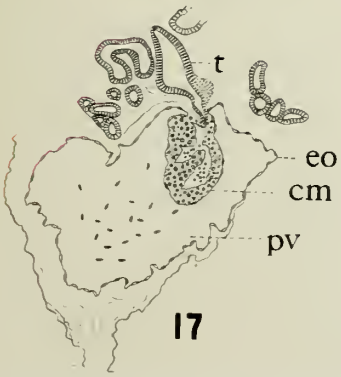

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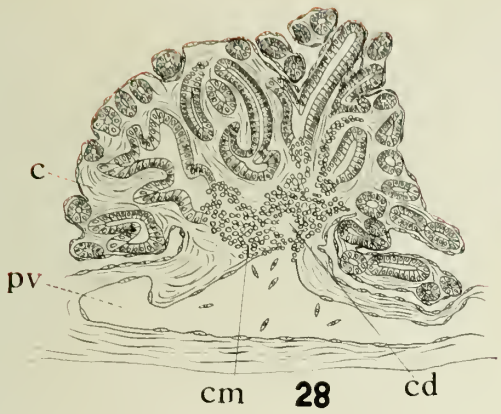
PLATE IV



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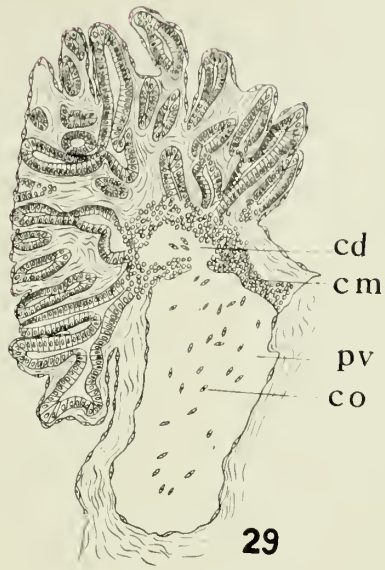

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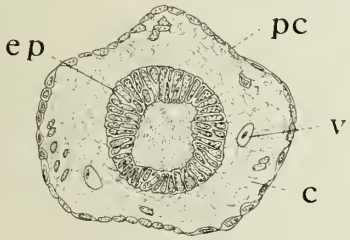

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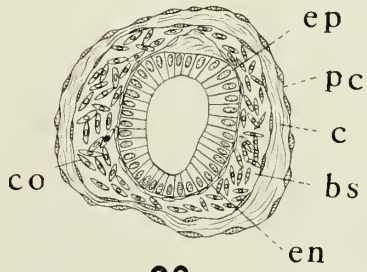

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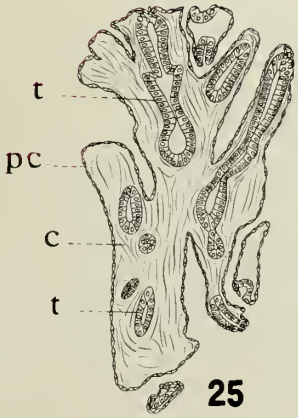

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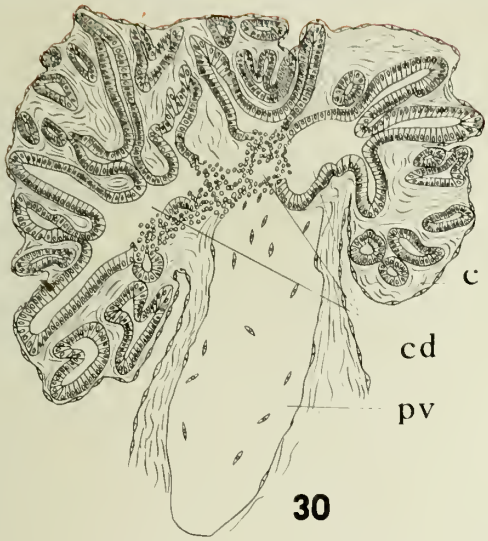
PLATE V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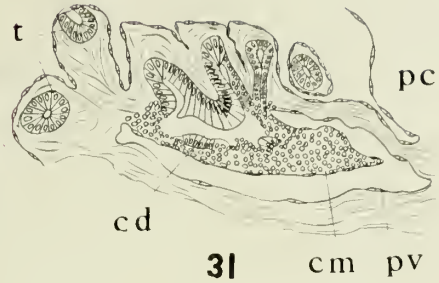
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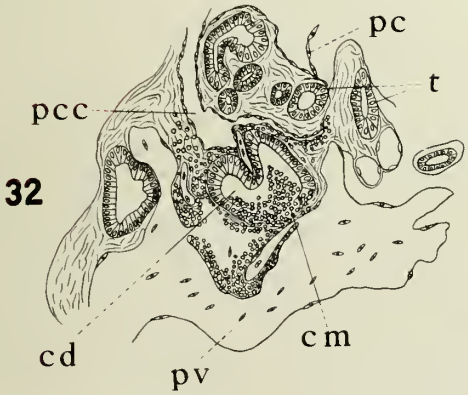
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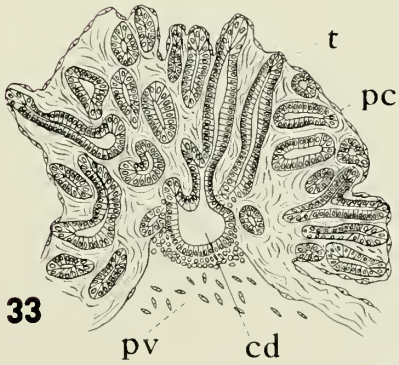
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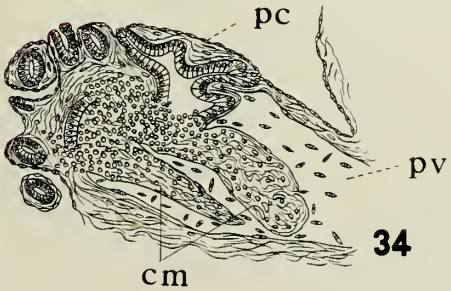
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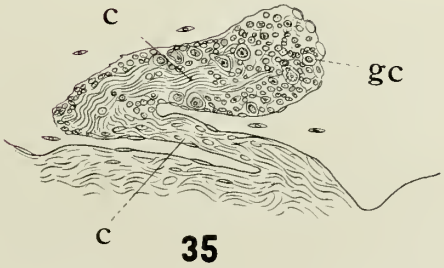
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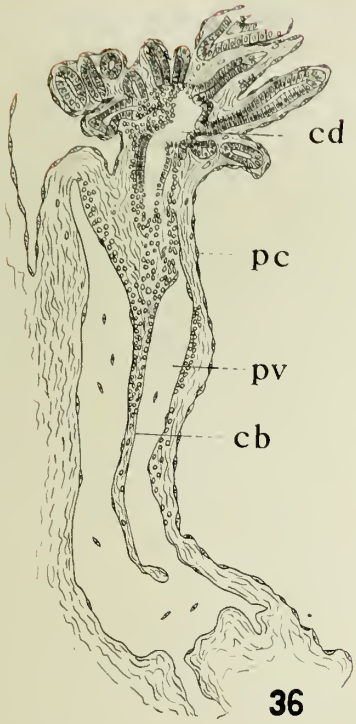
PLATE VI



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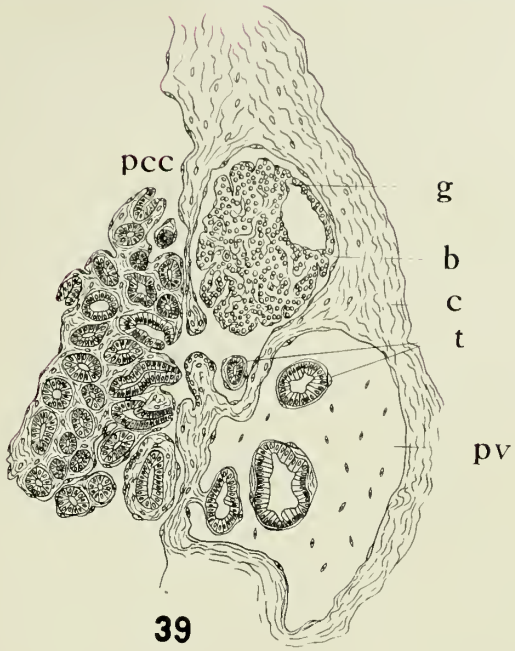

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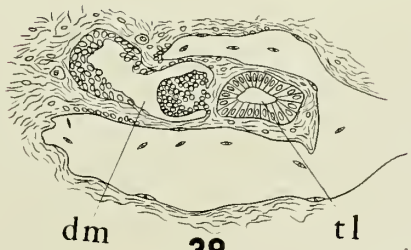

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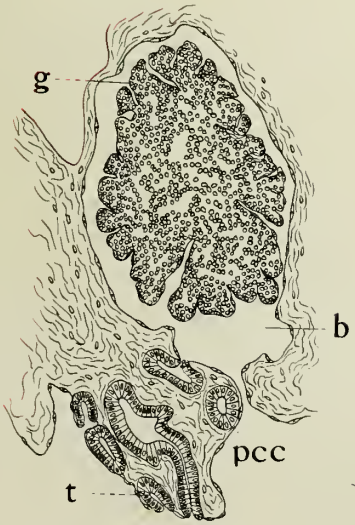

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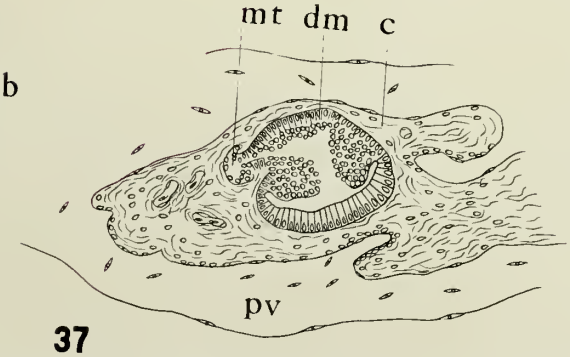

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PLATE VII

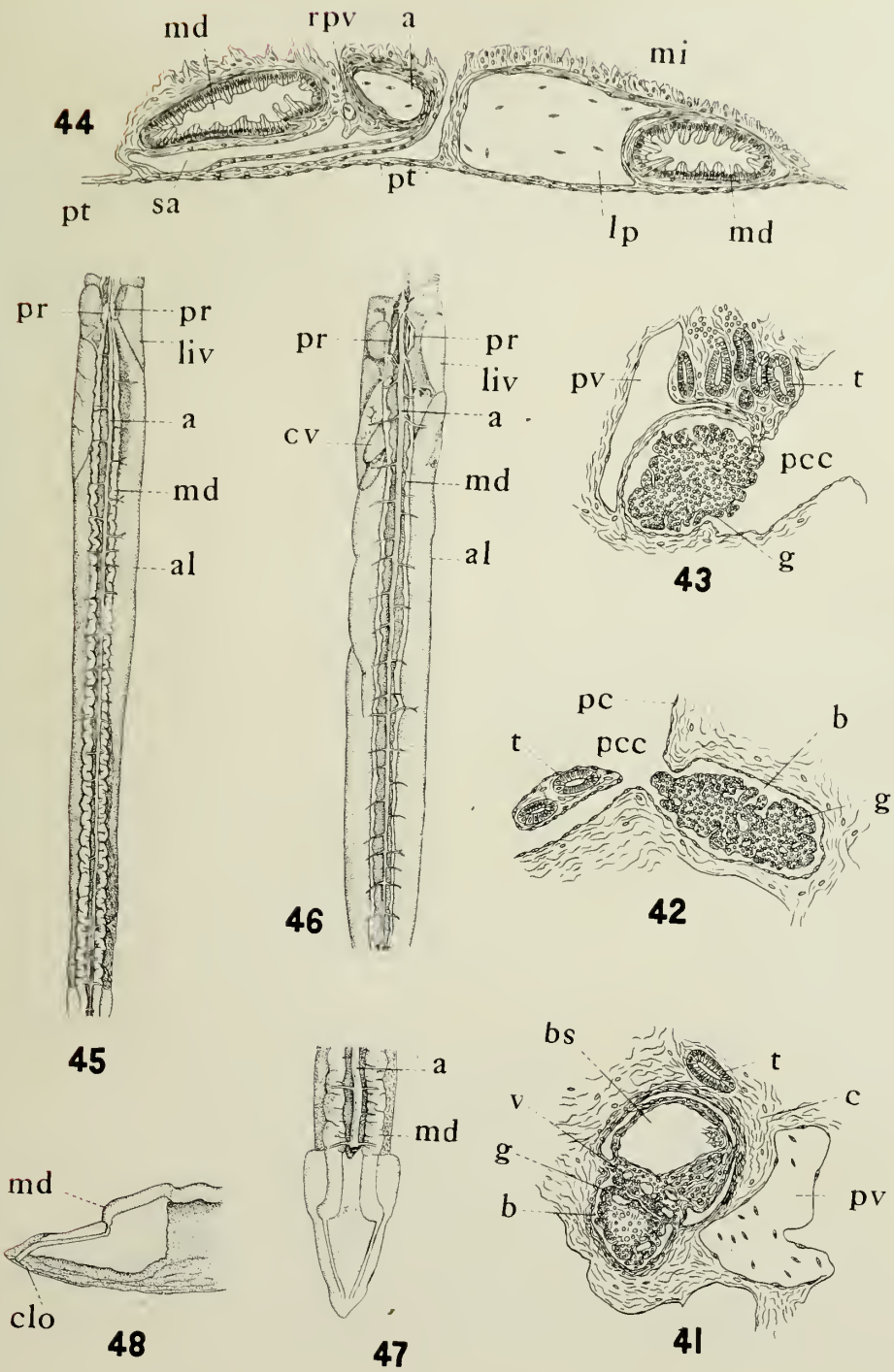
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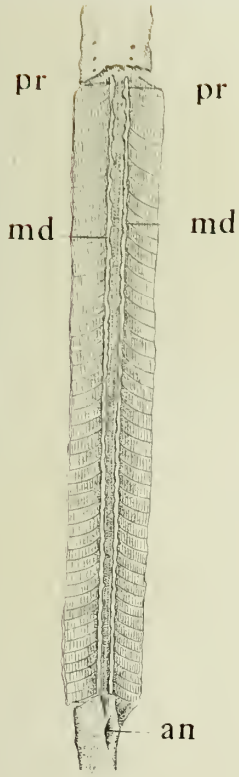
PLATE VIII



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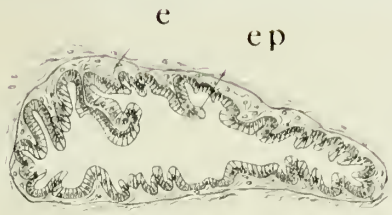

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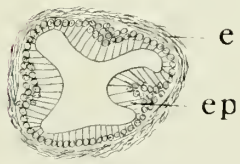

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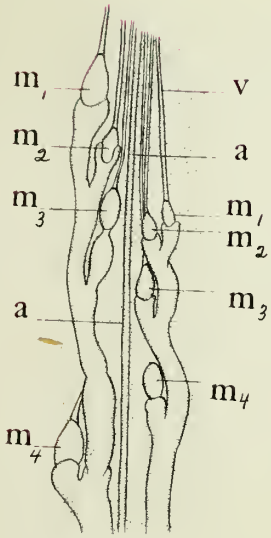

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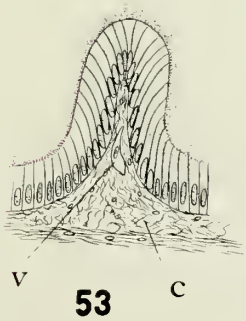

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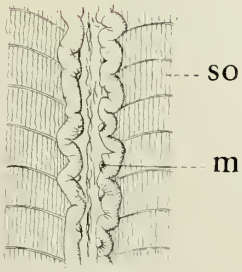

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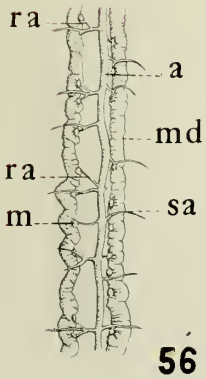

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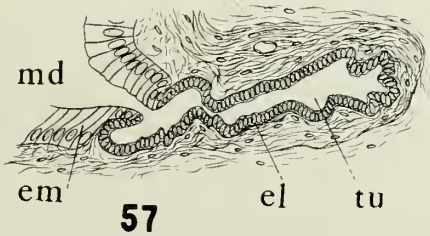

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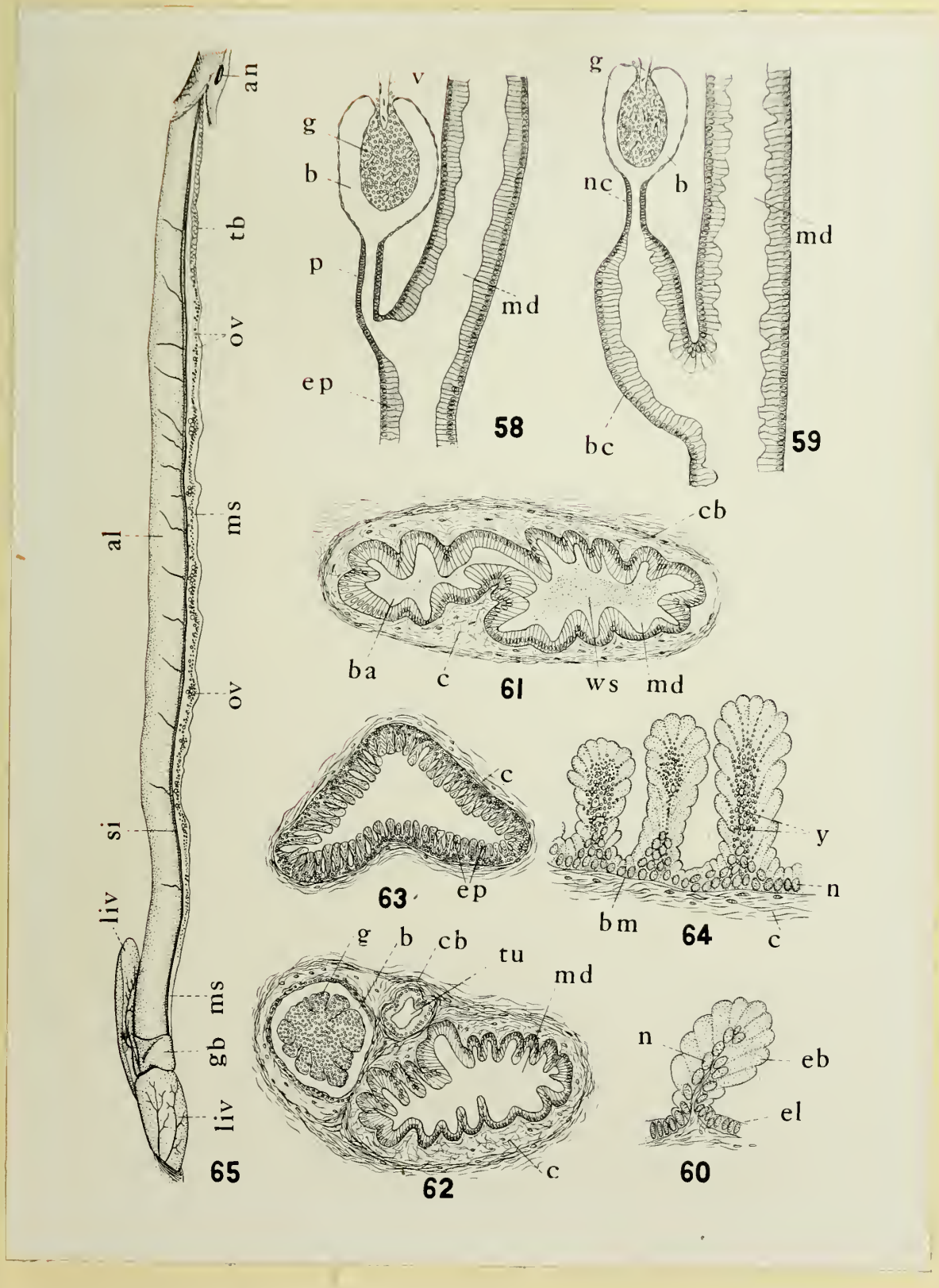
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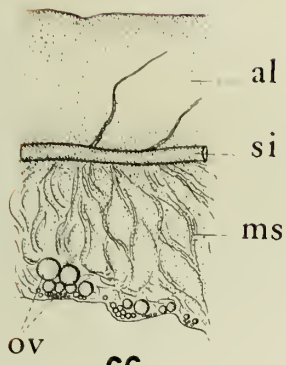
PLATE X



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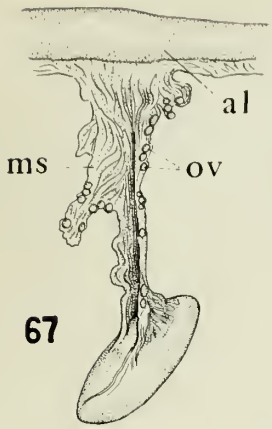

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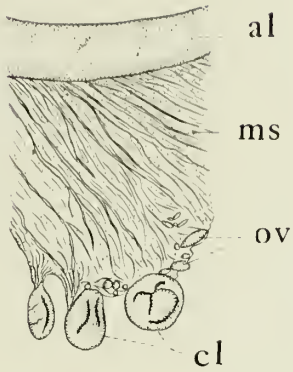

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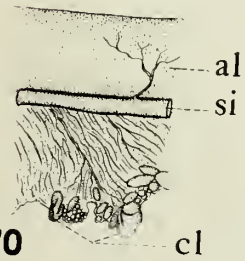

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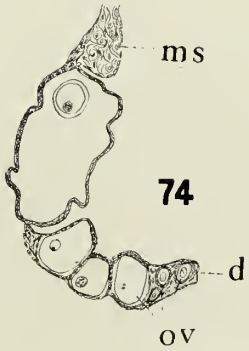

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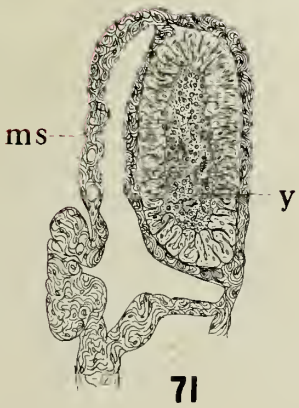

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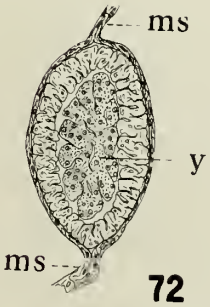

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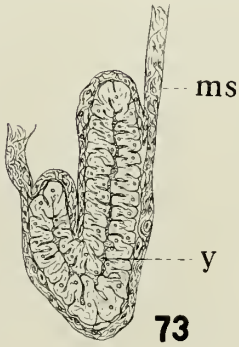

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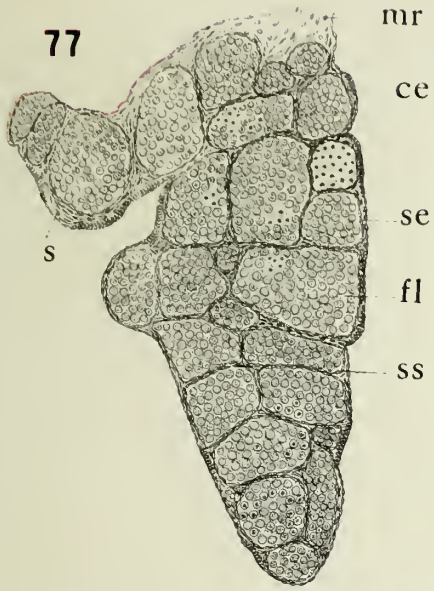
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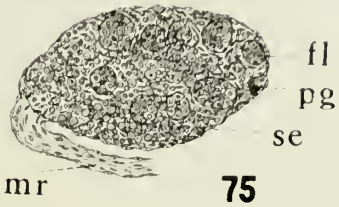
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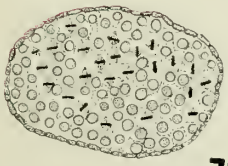
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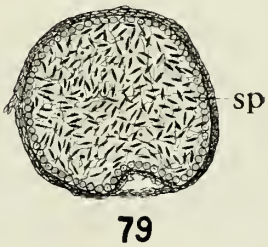
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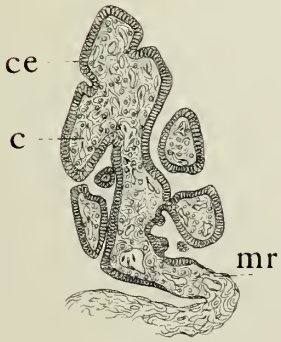
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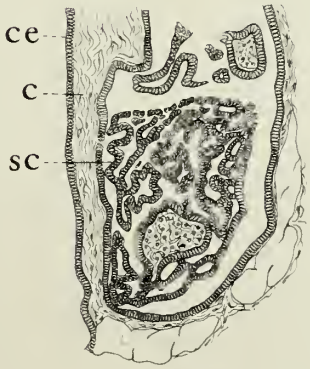
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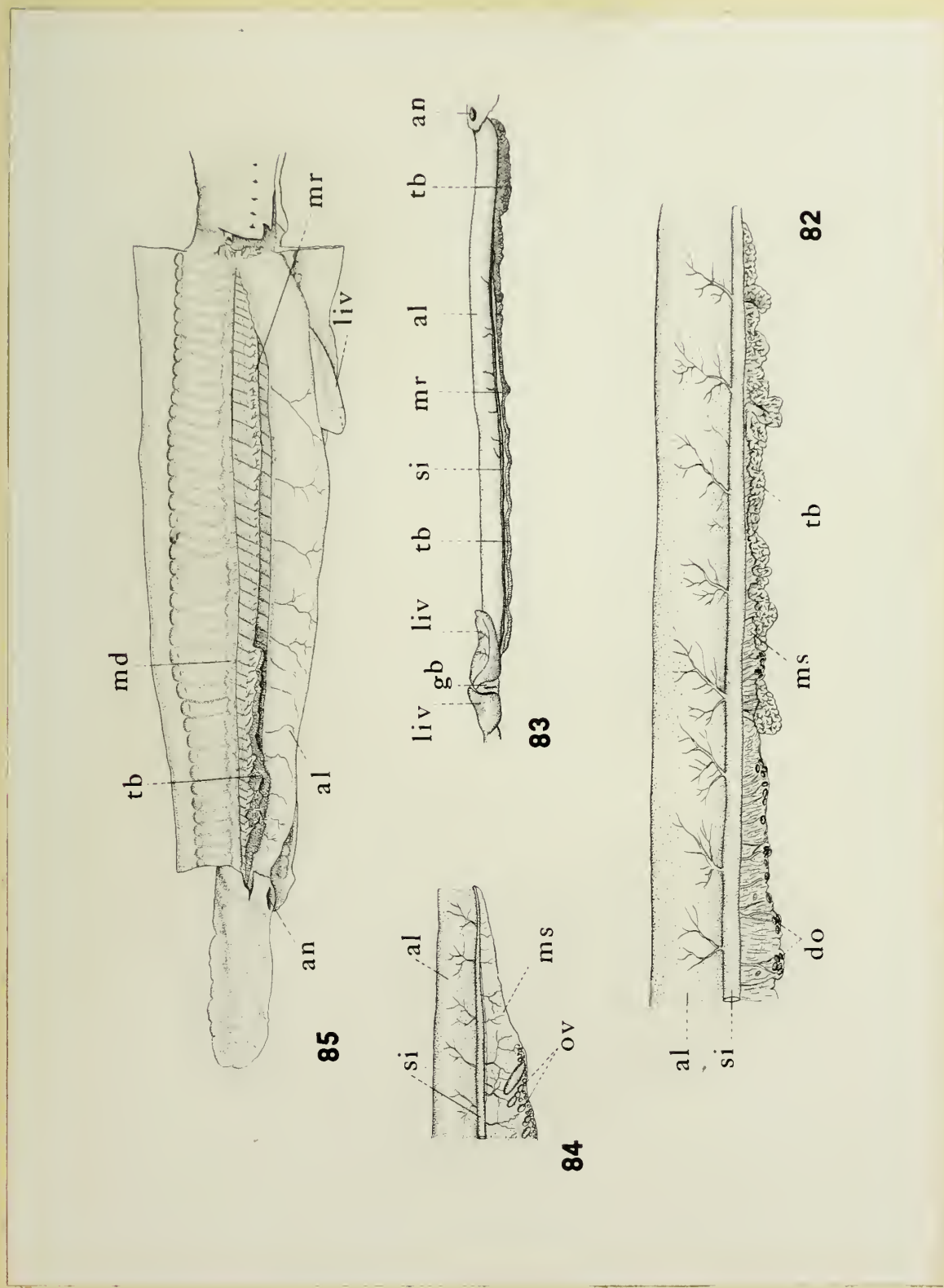
PLATE XII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VITA

1883, January 31, born in Christian County, near Mt. Auburn, Illinois

1891-1895, attended the public schools in Decatur, Illinois

1899, graduated from High School, Decatur, Illinois

1909-1912, attended James Millikin University, Illinois
1911-1912, Assistant in Zoology, James Millikin University
1912, received A. B. degree, with high honors, James Millikin University

1912-1913, Scholar at University of Illinois

1913, received M. A. degree, University of Illinois

1913, in charge of Biology during the summer term at the Northern Illinois State Normal School

1913-1914, Fellow at University of Illinois

1914, elected to membership in Sigma Xi, University of Illinois

1914, spent the summer at Harpswell Laboratory, on the coast of Maine

1914-1915, half- and full-time Graduate Assistant in Vertebrate Zoology, University of Illinois

1915, spent the summer at Harpswell Laboratory, Maine

1915-1916, full-time Graduate Assistant in Vertebrate Zoology, University of Illinois

Publications:

"A study of the brown-rot fungus in the vicinity of Champaign and Urbana, Illinois." Phytopathology, 4; 93-101, 1914.

"A study of ganglion cells in the sympathetic nervous system, with special reference to intrinsic sensory neurones." With Dr. F. W. Carpenter, Journ. Comp. Neur., 24; 269-281, 1914.

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